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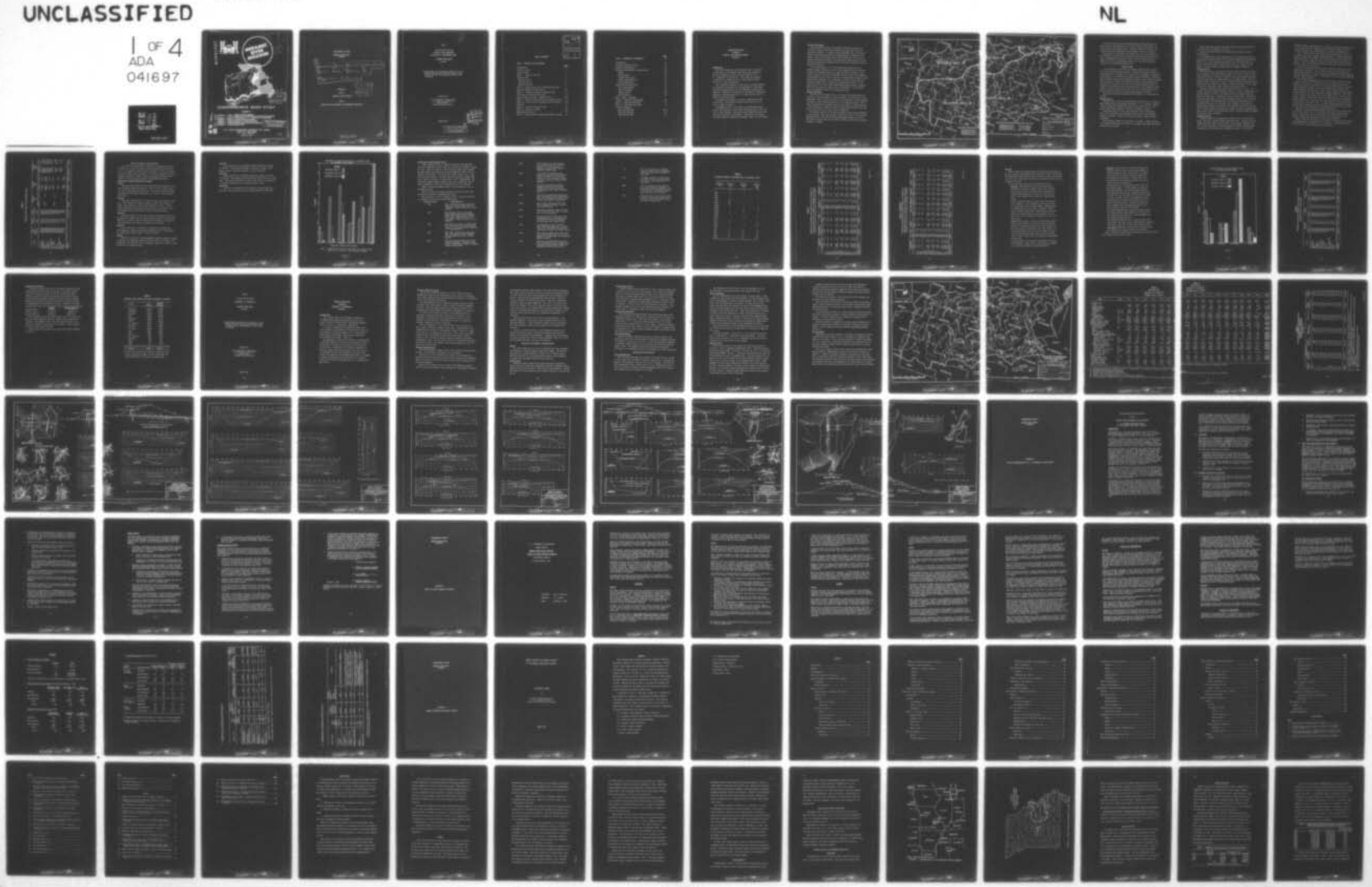

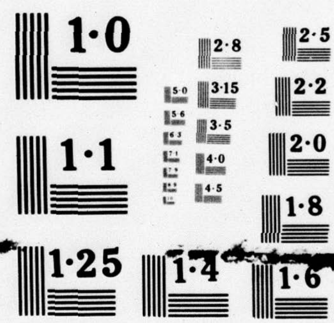
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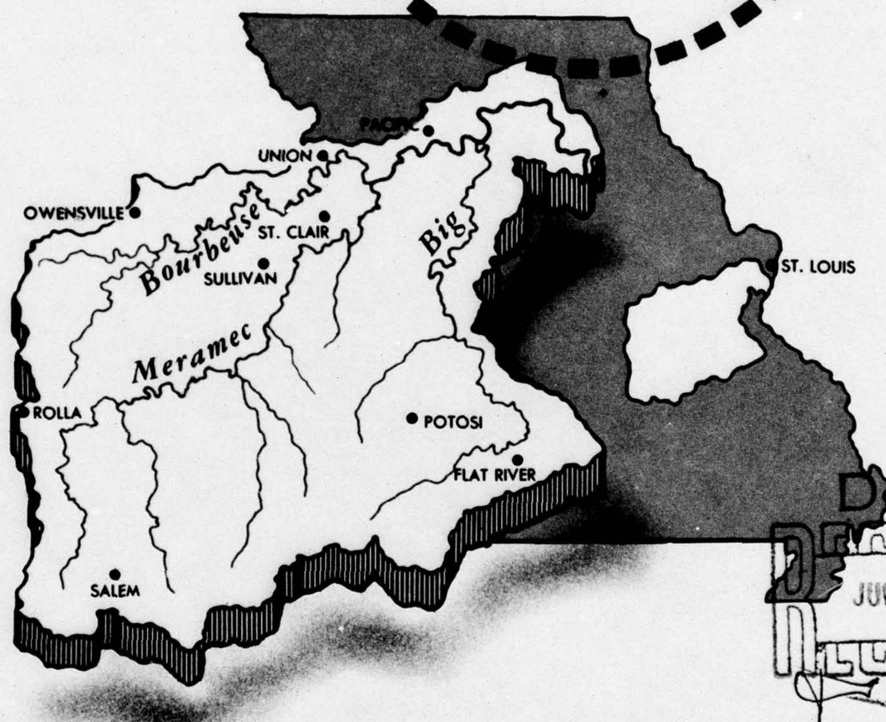

COMPREHENSIVE BASIN STUDY

VOLUME VI

APPENDIX G – (Part 1) PHYSICAL LAND CONDITION
(Part 2) DESIGN AND COST ESTIMATES FOR HEADWATER RESERVOIRS
APPENDIX H – PLAN OF PARTICIPATION BY U. S. DEPARTMENT OF AGRICULTURE
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U. S. ARMY ENGINEER DISTRICT, ST LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI
JANUARY 1964

186

COMPREHENSIVE REPORT

MERAMEC RIVER BASIN,
MISSOURI

(6) Meramec River, Missouri Comprehensive Basin Study. Volume VI. Appendices G thru L.

(11) Jan 64

APPENDIX G

(12) 296p.

PART 1

PHYSICAL LAND CONDITION

PART 2

DESIGN AND COST ESTIMATES FOR HEADWATER RESERVOIRS

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PART 1

Interim Survey Report

PHYSICAL LAND CONDITIONS AS RELATED TO AGRICULTURAL USES

MERAMEC RIVER BASIN

Missouri

Prepared Under the Authority of Section 6 of the Watershed Protection and Flood Prevention Act (Public Law 566, 83rd Congress; 68 Stat. 666), as amended.

Prepared by:

U. S. Department of Agriculture
Soil Conservation Service
Forest Service
Economic Research Service

August, 1963

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PART 1 - PHYSICAL LAND CONDITIONS

MERAMEC RIVER BASIN
(INTERIM)
PHYSICAL LAND CONDITION REPORT
MISSOURI

Introduction

This interim physical land condition report, as related to agriculture in the Meramec River Basin, was prepared by the Soil Conservation Service and Forest Service of the U. S. Department of Agriculture. This report was prepared in response to a request by the St. Louis District Office of the U. S. Corps of Engineers.

The information contained in this report is based primarily on information contained in the 1959 National Soil and Water Conservation Needs Inventory of the Department of Agriculture. Additional information was supplied by the Missouri Conservation Commission cooperating with the U. S. Forest Service and the Missouri Geological Survey.

The Meramec River Basin is an area of approximately 3980 square miles. The watershed boundaries and location of the basin is shown in Figure 1.

The Meramec River is a tributary of the Mississippi River joining the Mississippi about twenty (20) miles south of the city of St. Louis, Missouri. The Big and the Bourbeuse Rivers are the two main tributaries of the Meramec. These three (3) streams with their numerous tributaries thoroughly disect the entire basin.

Geology of the Basin

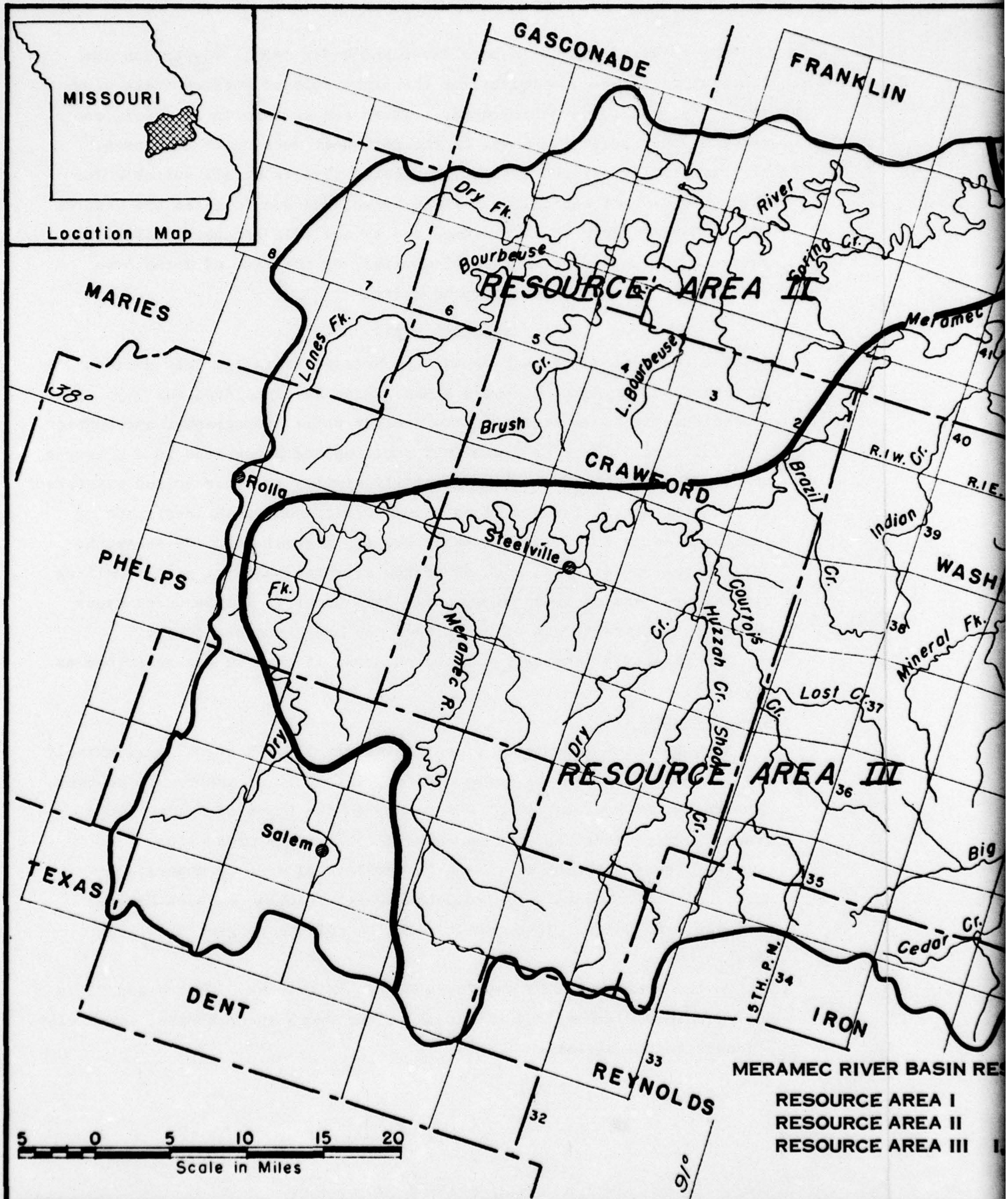
The rocks which outcrop in the greater portion of the basin are principally dolomite and flinty dolomite with some beds of brown or grey-brown sandstone. At places in the southeastern part of the basin granites and associated lavas of Pre-Cambrian Age are exposed at the surface. Much of the upland area of the northern part of the basin is capped with shales and clays of the Des Moines formation which lie upon the cherty dolomite and sandstone beds of the Cotter-Jefferson City and Roubidoux formations.

In the western part of St. Louis County and adjacent parts of Jefferson County outcrops of the St. Peter sandstone and the overlying dolomite and limestone beds of the Ordovician Age are exposed. These strata are seen in the bluffs which make the valley walls of the Meramec and Big Rivers in the vicinity of Pacific, House Springs and Eureka. Below Valley Park the Meramec, as it approaches its mouth, flows across geologically younger beds of limestone of the Mississippian Age. In the eastern part of St. Louis County these Mississippian beds are covered in places at the surface by shales and thin limestones of the Des Moines group of sedimentary rocks of the Pennsylvanian Age.

Soils of the Basin

The soils in the greater portion of the basin are characteristic of the soils of the Ozark Region - shallow, cherty, or stony soils on steep topography. This is especially true in the southern part of the watershed with some of these conditions existing in the remaining portion. Due to these land features the southern portion of the basin is largely devoted to the production of timber with some relatively small areas of open farm land, such as the area in the vicinity of Belgrade.

The northern portion of the basin has deeper soils and the topography is not as steep. Deep, well-drained loessial soils occur in the extreme northeastern part with the loess capping becoming thinner to the west. This section of the basin has some steep, shallow, rocky soils, especially adjacent to streams.


MISSOURI
Location Map
GASCONADE
FRANKLIN
MARIES
PHELPS
CRAWFORD
WASH
TEXAS
DENT
IRON
REYNOLDS
RESOURCE AREA II
RESOURCE AREA III
Rolla
Steelville
Salem
Dry Fk.
Bourbeuse
River
Spring Cr.
Meramec
Lanes Fk.
Brush Cr.
L. Bourbeuse
Brazil Cr.
R.1W.
R.1E.
Indian
Courtois
Huzzah Cr.
Mineral Fk.
Lost Cr.
Meramec R.
Dry Cr.
Shoal Cr.
Dry Fk.
Big
Cedar Cr.
5TH. P.M.
38°
91°
MERAMEC RIVER BASIN RES
RESOURCE AREA I
RESOURCE AREA II
RESOURCE AREA III
5 0 5 10 15 20
Scale in Miles

I

MERAMEC RIVER BASIN RESOURCE AREA MAP

RESOURCE AREA I	128,194 ACRES
RESOURCE AREA II	734,595 ACRES
RESOURCE AREA III	1,684,411 ACRES

Scale: 1:500,000

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Project No. ________ Map No. ____
Source of Data ________
Compiled by ________ Date 11-28-62
Bureau ________
Approved ________ Bureau. ____

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The soils of the basin were developed under timber vegetation for the most part, which accounts for the light colored surface soils, low fertility, and low organic matter. There are some soils, however, developed under prairie grasses in the northwest section of the basin.

Practically all the land in the basin, that is at all suitable for the production of agricultural field crops, has been cleared and used as such. Considerable areas of this land is now idle because the soil pattern, the levels of management applied, or the size of farms have resulted in non-economical farming units.

RESOURCE AREAS

For the purpose of this report the Meramec Basin has been divided into three (3) general Resource Areas. Each Resource Area has physical conditions which, in general, have similar soils, topography, and physical land features. It is believed that small upland watersheds in a Resource Area will have characteristics generally similar to other upland watersheds in the same area. These will be somewhat different than watersheds of similar size in either of the other two (2) general Resource Areas. Localized soil conditions, such as narrow alluvial valleys, gently rolling ridges, or areas of steep stony soils will occur in all Resource Areas but in different pattern of occurrence and proportionate extent.

The three (3) generalized Resource Areas (Figure 1) are described as follows:

Resource Area I

Resource Area I consists of approximately 128,194 acres, a relatively small segment (5%) of the Meramec River Basin. It is important, however, from the watershed standpoint due mainly to the types of soils, topography, and present land use as related to sediment production.

The greater portion of this area consists of deep to moderately deep, well to moderately well-drained loessial soils, such as Memfro, Winfield, and Union. These soils occur on rolling to gently rolling topography.

On the steeper slopes the loess mantle is thinner. Cherty and rocky soils (mainly Clarksville) are found on the rough steep slopes, especially adjacent to the streams.

First bottoms are generally well-drained and very good agricultural soils except for the hazards of overflow.

Soils of the second bottom vary from deep, well-drained to very poorly drained.

It is estimated that 33% of Resource Area I is being used for cultivated crops and a small percent of this land is adequately protected from erosion. It is also estimated that another 15% of Resource Area I is used as "Other Land" which includes roads, lots, etc., where the land surface is being disturbed causing additional sediment production.

Resource Area II

Area II consists of approximately 734,595 acres or 28.8% of the basin. Gently sloping to flat ridge tops are common in this area. Most of this ridge land has been cleared and is farmed. The soils are generally underlain with heavy clay on a dense cemented silty fragapan layer. They are normally slowly drained and limited in available moisture storage capacity. Susceptibility to erosion is a problem. Lebanon and Gerald are the common soil series. The gentle slopes are generally Dickson soils.

The down slopes from these ridges vary from rolling to steep. The rolling slopes are normally moderately deep soils, such as Clarksville and Fulerton cherty silt loams. The steeper slopes are generally shallow, cherty and rocky soils - Clarksville cherty or rocky loams. The depth of the soil and steepness of the slopes determines whether or not this land is being farmed. Low available moisture storage and susceptibility to erosion are the major soil problems. Also included in this area are numerous small alluvial valleys which are generally farmed quite intensively. The soils (mostly Huntington silt loam) are deep, well-drained and produce good yields of all agricultural crops. The major hazard in farming this type of land is overflow.

Resource Area III

Area III consists of approximately 1,684,411 acres or 66.2% of the basin. This area is mainly rough, steep stony soils. The main soils are Clarksville stony loams on steep slopes. The slopes are generally over 15%. Cliffs are common, especially adjacent to streams. Narrow ridges with shallow, cherty soils occur throughout the area. Low available

moisture storage, inaccessibility to cropping, and erosion susceptibility are the major problems. Numerous narrow alluvial valleys with soils varying from deep, well-drain materials to infertile outwash occur.

Due to these physical land conditions of the main part of this area the present land use is largely timber production. Primary products are rough oak lumber, pine lumber, pine posts and poles, and railroad ties. Some of the narrow ridges have been cleared and used for field crops or pasture. Most of the alluvial valleys are open land, generally in pasture with some row crops grown.

There are some relatively small areas included in Area III that are significantly different. One of these is located in the vicinity of Belgrade and Caledonia. The section consists of gently rolling topography with good deep soils in general. Practically all of this land is open and used for general farming.

In the extreme southeastern section of the basin is an area of flat to gently rolling land. These soils are not as productive as in the Belleview valley but the greater portion is open land and used for field crops and pasture purposes. Also, in this section are areas of tiff (barium sulfate) and lead mines. Both of these mining operations disrupt the land surface and cause considerable sediment production. Many acres of this land will not produce any type of vegetation as a result of lead mining. Another sizeable area in the tiff mining area may be capable of producing some type of wood products. Iron mining is being investigated in this area at the present time. If these investigations prove successful and mining increases, additional acreage of waste land will be added in the area as well as additional sediment production.

Some other dispersed areas of Resource Area III are not as steep and with broader ridges. Soils of these areas are generally shallow and cherty. A higher percent of this land has been cleared than in the steeper sections and used mainly for small grain and grass.

Table 1 shows the approximate area of each of the fifteen (15) counties in the Meramec Basin, the percent of the counties in each Resource Area, and the percent of each Resource Area of the basin.

TABLE 1

PERCENT COUNTY AREA IN EACH RESOURCE AREA

County	Total Land Area in County	Percent of County in Basin	Acres of County in Basin	Resource Area I		Resource Area II		Resource Area III	
				Acres	%	Acres	%	Acres	%
Crawford	486400	100.00	486400			121600	25.00	364800	75.00
Washington	486400	99.70	484941					484941	99.70
Franklin	596480	64.00	381747	48817	8.2	199974	33.50	132956	22.30
Dent	483800	59.74	289024			130270	26.90	158754	32.84
Jefferson	426880	50.19	214272					214272	50.19
Phelps	433280	41.00	177645			92315	21.30	85530	19.70
St. Francois	292500	40.00	117000					117000	40.00
Gasconade	332800	34.07	113408			113408	34.07		
St. Louis	357120	28.00	99994	79377	22.2			20617	5.80
Iron	354600	22.00	78012					78012	22.00
Maries	336640	21.52	72448			72448	21.52		
Ste. Genevieve	320000	6.73	21535					21535	6.73
Reynolds	526100	1.17	6194					6194	1.17
Osage	384640	0.48	1860			1860	0.48		
Texas	757120	0.35	2720			2720	0.35		
TOTALS:			2,547,200	128,194	5	734,595	28.80	1,684,411	66.20

LAND USE CAPABILITY CLASSIFICATION

All land can be classified according to its capability for agricultural use. It will be noted in the following definitions of the U. S. D. A. Capability Classification that Class I to IV are suitable for a wide range of uses and Class V to VIII are principally suited for permanent vegetation. Figure 2 shows the estimated percent of each capability class by Resource Area for the Meramec River Basin.

Definitions of Land Use Capability Classes

Class I

Very good land suitable for all agricultural crops adapted to the area (including timber ,and wildlife). Must be level or nearly level with high or moderately high fertility. No special hazards in farming this land such as wetness, droughtiness, or erosion. Can be farmed intensively.

Class II

Very good land suitable for all agricultural crops adapted to the area. This land may be slightly droughty, slightly wet, may have a slight erosion hazard, or may be any combination of these. Can be farmed intensively providing conservation practices are used to overcome hazards such as contouring, in case of an erosion hazard.

Class III

Good land suitable for all agricultural crops adapted to the area. The hazards of farming this land are the same as Class II land but more difficult to overcome. May be farmed rather intensively if protected from hazards such as terracing, if erosion is the problem.

Class IV

This is land that is suitable for limited row crop production even though all conservation practices needed are used - more suitable for production of grass, timber, or use as wildlife.

Class V

Land that is suitable for only permanent vegetation (grass or timber) or wildlife. No hazards in using this land if used in this manner. Includes flat, wet land that is not economically feasible to drain, or flat land that is too stony to clear.

Class VI

Land suitable for only permanent vegetation (grass or timber) or wildlife. The hazards are simple to overcome if used in this manner, such as controlled grazing, in case of grassland.

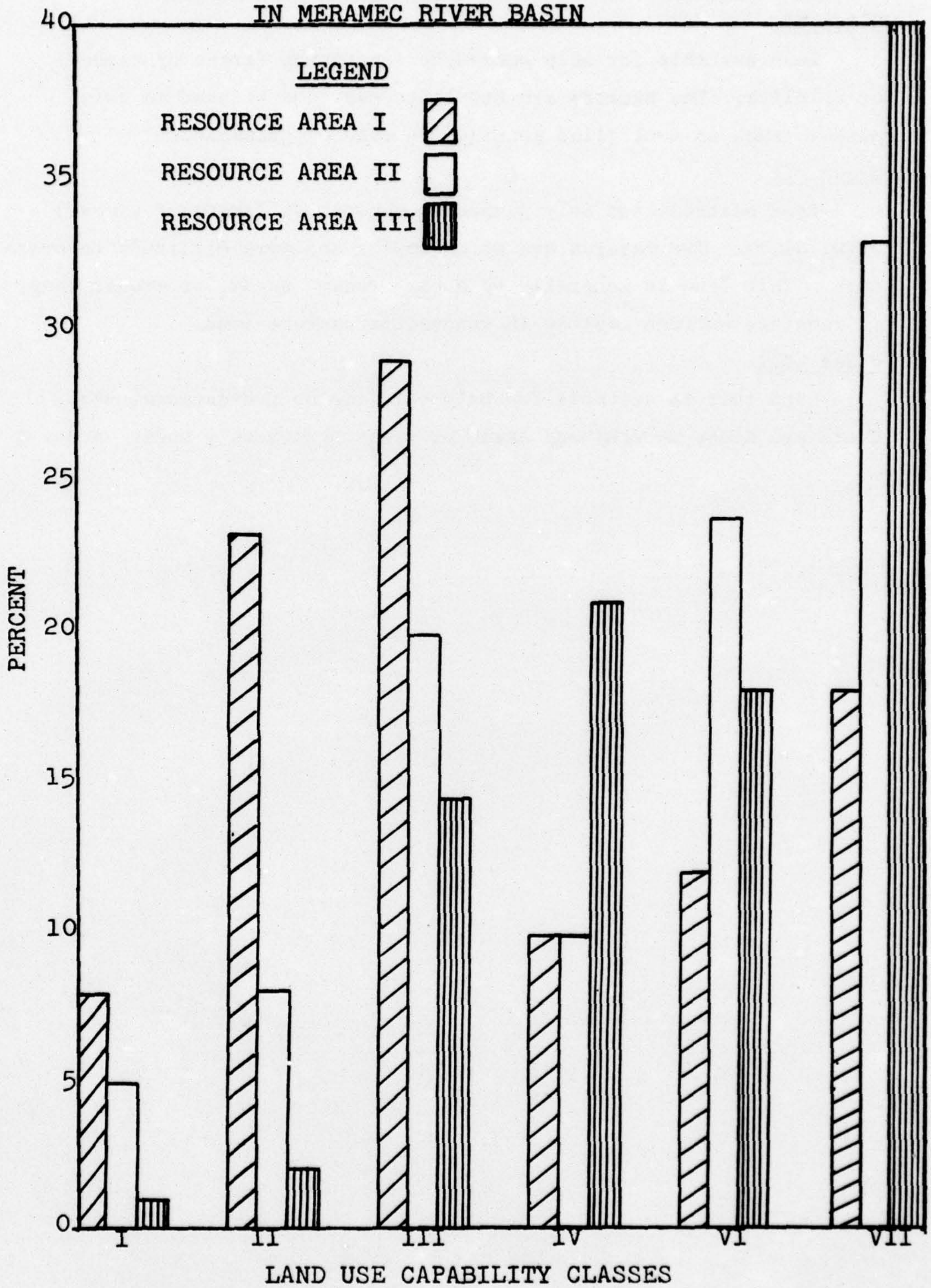
Class VII

Land suitable for only permanent vegetation (grass or timber) or wildlife. The hazards are more complex and more difficult to overcome. This land is generally so steep, rocky, sandy, or eroded that it requires extreme caution in renovating pasture land.

Class VIII

Land that is suitable for only wildlife or recreational use. These are steep mountainous areas or areas permanently under water.

ESTIMATED CAPABILITY CLASSES BY RESOURCE AREA
IN MERAMEC RIVER BASIN



Note: Capability Classes V and VIII not shown since they do not occur in significant amounts.

Figure 2

Definitions of Land Capability Unit

A land capability unit is a group of physical land conditions which have reasonably similar kinds and intensities of hazards in using the land. These are shown by a three (3) digit symbol such as IIIe6. The Roman Numeral III indicates the broad capability class or the intensity of the hazards. The second digit (small letter e,w,s,) indicates the major problem - "e" means the major problem in farming this type of land is erosion, "w" excess water, and "s" droughtiness. The third digit (Arabic Number) indicates major soil properties, such as depth, permeability, and water holding capacity of soil material.

Table 2 shows the estimated percent of each capability unit in each Resource Area.

Table 2-a shows the estimated acreage and percent of each capability unit by counties in Meramec River Basin.

The following is a list of capability units and definitions that is estimated will be found in the Meramec Basin:

CAPABILITY UNITS	CHARACTERISTICS
IIe1	Deep, well-drained upland and bottomland soils with favorable subsoils, occurring on gentle slopes with slight erosion.
IIe2	Well-drained soils with favorable upper subsoils that occur on gentle slopes with slight erosion, and have rock, sand, or gravel at 20 to 36 inch depths. These soils are a little droughty.
IIe6	Deep soils that occur on gentle slopes with slight erosion and with subsoils that are a little heavy and of moderate to slow permeability.
IIw1	Deep, dark colored soils occurring on flat areas that have heavy subsoils and are imperfectly and too slowly drained.
IIIe1	Deep, well-drained upland soils with favorable subsoils, occurring on moderately eroded gentle slopes or slightly eroded rolling slopes.

IIIe2	Well-drained soils with favorable upper subsoils and rock, sand, or gravel at 20-36 inch depths on moderately eroded gentle slopes or uneroded rolling slopes.
IIIe3	Soils on gentle uneroded slopes, having well-drained, favorable upper layers with rock, sand, or gravel within 12 to 20 inch depths. Surface soils may be cherty and these may be droughty.
IIIe5	Soils with very heavy (claypan or hardpan) subsoils with very slow permeability on gently sloping to rolling areas with slight to moderate erosion.
IIIe6	Deep soils with moderately heavy subsoils of moderate to slow permeability. They occur on moderately eroded gentle slopes and uneroded rolling slopes.
IIIw3	Nearly level, gray soils with very heavy (claypan or hardpan) subsoils, very slowly drained.
IIIs1	Areas with favorable surface and subsoils but having rock, sand, or gravel at 12 to 20 inch depths.
IVe1	Well-drained, deep upland soils with favorable subsoils on rolling slopes with moderate erosion and steeply rolling slopes with slight erosion.
IVe2	Well-drained soils with favorable upper layers and rock, sand, or gravel at 20 to 36 inch depths occurring on eroded gentle slopes with slight erosion.
IVe3	Soils with favorable upper layers and rock, sand, or gravel at 12 to 20 inch depths on rolling slopes with slight and moderate erosion.
IVe6	Deep soils with moderately heavy subsoils of moderate to slow permeability occurring on eroded gentle slopes and moderately eroded rolling slopes.

VIe	All "e" problem soils on slightly eroded or steep slopes with moderate and severe erosion are included in this class.
VIs	All sandy, gravelly, or stony soils on steep or very steep slopes where cultivation is not practical are in this class.
VIIe	All "e" problem soils are found on very steep slopes with moderate and severe erosion and on moderately stony or sandy soils in strongly rolling areas that have severe erosion.
VIIs	Sandy, gravelly, or stony soil areas on steep or very steep slopes, or very severely eroded areas on all slopes, are placed in this class.

TABLE 2

ESTIMATED PERCENT OF RESOURCE AREA BY CAPABILITY UNITS

Capability Units	Resource Area I	Resource Area II	Resource Area III
I	8	5	1
IIe1	8		
IIe2		7	1
IIe6	5		
IIw1	10	1	1
IIIe1	20		
IIIe2	3		
IIIe3		7	5
IIIe5		10	5
IIIe6	6		
IIIw3		1	1
IIIs1		2	4
IVe1	3		
IVe2	4	7	10
IVe3		3	11
IVe6	3		
VIe	8	10	8
VIs	4	14	10
VIIe	10	13	18
VIIs	8	20	25

TABLE 2a

ESTIMATED DISTRIBUTION AND EXTENT (ACRES AND PERCENT) OF
EACH CAPABILITY UNIT BY COUNTIES IN MERAMEC RIVER BASIN
(Figures include only that portion of county in basin)

	CRAWFORD		WASHINGTON		DENT		FRANKLIN		JEFFERSON		PHELPS		ST. FRANCOIS	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
I	9728	2.0	4849	1.0	8102	2.8	15234	4.0	2142	1.0	5469	3.0	1170	1.0
IIe1							3905	1.0						
IIe2	12160	2.5	4849	1.0	10707	3.7	15328	4.0	2142	1.0	7315	4.1	1170	1.0
IIe6							2441	.6						
IIw1	4864	1.0	4849	1.0	2891	1.0	8212	2.2	2142	1.0	1776	1.0	1170	1.0
IIIe1							9763	2.6						
IIIe2							1465	.4						
IIIe3	26752	5.5	24247	5.0	17057	5.9	20646	5.4	10714	5.0	10729	6.0	5850	5.0
IIIe5	30400	6.3	24247	5.0	20962	7.2	26645	7.0	10714	5.0	13499	7.5	5850	5.0
IIIe6							2929	.8						
IIIw3	4864	1.0	4849	1.0	2891	1.0	3330	.9	2142	1.0	1776	1.0	1170	1.0
IIIs1	17024	3.5	19398	4.0	8955	3.1	9317	2.4	8571	4.0	5259	3.0	4680	4.0
IVe1							1465	.4						
IVe2	44992	9.2	48494	10.0	24994	8.6	29247	7.7	21427	10.0	14995	8.4	11700	10.0
IVe3	43776	9.0	53343	11.0	21371	7.3	20624	5.4	23570	11.0	12155	6.8	12870	11.0
IVe6							1465	.4						
VIe	41344	8.5	38797	8.0	25727	9.0	34536	9.0	17142	8.0	16058	9.1	9360	8.0
VIs	53504	11.0	48494	10.0	34113	11.9	43245	11.3	21427	10.0	21457	12.1	11700	10.0
VIIe	81472	16.8	87289	18.0	45511	15.8	54811	14.3	38570	18.0	27361	15.4	21060	18.0
VIIs	115520	23.7	121236	25.0	65743	22.7	77139	20.2	53569	25.0	39796	22.5	29250	25.0
TOTALS:	486400		484941		289024		381747		214272		177645		117000	

TABLE 2a (CONTINUED)

ESTIMATED DISTRIBUTION AND EXTENT (ACRES AND PERCENT) OF

EACH CAPABILITY UNIT BY COUNTIES IN MERAMEC RIVER BASIN

(Figures include only that portion of county in basin)

	GASCONADE		ST. LOUIS		MARIES		IRON		STE.GENEVIEVE		REYNOLDS		TEXAS		OSAGE	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
I	5670	5.0	6556	6.6	3622	5.0	780	1.0	215	1.0	62	1.0	136	5.0	93	5.0
IIe1			6350	6.4												
IIe2	7939	7.0	206	.2	5071	7.0	780	1.0	215	1.0	62	1.0	190	7.0	130	7.0
IIe6			3969	4.0												
IIw1	1134	1.0	8144	8.1	724	1.0	780	1.0	215	1.0	62	1.0	27	1.0	19	1.0
IIIe1			15875	15.8												
IIIe2			2381	2.4												
IIIe3	7939	7.0	1031	1.0	5071	7.0	3901	5.0	1077	5.0	310	5.0	190	7.0	130	7.0
IIIe5	11341	10.0	1031	1.0	7245	10.0	3901	5.0	1077	5.0	310	5.0	272	10.0	186	10.0
IIIe6			4763	4.8												
IIIw3	1134	1.0	206	.2	724	1.0	780	1.0	215	1.0	62	1.0	27	1.0	19	1.0
IIIs1	2268	2.0	825	.8	1449	2.0	3121	4.0	861	4.0	248	4.0	54	2.0	38	2.0
IVe1			2381	2.4												
IVe2	7939	7.0	5237	5.2	5071	7.0	7801	10.0	2154	10.0	619	10.0	190	7.0	130	7.0
IVe3	3402	3.0	2268	2.2	2173	3.0	8581	11.0	2369	11.0	681	11.0	82	3.0	56	3.0
IVe6			2381	2.4												
VIe	11341	10.0	7999	8.2	7245	10.0	6241	8.0	1723	8.0	496	8.0	272	10.0	185	10.0
VIs	15877	14.0	5237	5.2	10143	14.0	7801	10.0	2154	10.0	619	10.0	381	14.0	260	14.0
VIIe	14743	13.0	11650	11.6	9418	13.0	14042	18.0	3876	18.0	1115	18.0	354	13.0	242	13.0
VIIs	22681	20.0	11504	11.5	14492	20.0	19503	25.0	5384	25.0	1548	25.0	545	20.0	372	20.0
TOTAL:	113408		99994		72448		78012		21535		6194		2720		1860	

Page 2 of 2

Land Use

Figure 3 shows the estimated land use by Resource Areas based on the Soil and Water Conservation Needs Inventory of 1959. Even though the Conservation Needs Inventory does not contain recreation and wildlife uses, all of the land in this area of various uses does not have recreation potential.

The four (4) major land uses are defined as follows:

Cropland Land currently tilled, including cropland harvested, crop failure, summer fallow, idle cropland, land in cover crops or pastured rotation pasture, and cropland being prepared for crops or in newly seeded crops. Also includes land in tame hay, vegetables and fruits.

Upland rotations include row crops, which is generally corn, soybeans, or milo followed by small grain (wheat or oats) seeded to grass-legume meadow. Common grasses and legumes grown are red clover, lespedeza, ladino clover, alfalfa, brome grass, orchard grass, and fescue. Some of the upland areas are used primarily for hay while most of the bottomland is used for row crops and small grain.

Pasture Land in grass or other long-term forage growth that is used primarily for grazing. Pasture includes grassland, non-forested pasture, and other grazing land with the exception of pasture in the crop rotation. It may contain shade trees or scattered timber with less than ten (10) percent canopy, but the principal plant cover is such to identify its use primarily as permanent grazing land.

A large percent of the pasture land consists of grasses with lespedeza. Ladino clover, brome grass, and fescue are used to some extent for improved pastures.

<u>Woodland</u> Lands which are at least ten (10) percent stocked by forest trees of any size and capable of producing timber or other wood products, or capable of exerting an influence on the water supply have been classified as woodland. Forested areas that are primarily for recreational purposes are also included in this classification.

The woodland area is composed primarily of four (4) major forest types: (1) Oak-hickory, (2) Oak-pine, (3) Cedar-hardwoods, and (4) Bottomland hardwoods.

The oak-hickory type contains primarily mixed stands of black oak, post oak, white oak, scarlet oak, blackjack oak, bitternut hickory, and mockernut hickory.

The oak-pine type contains mixed stands of oak (all kinds) and shortleaf pine. In parts of Washington, Iron, Crawford, Dent, and Reynolds Counties, pine may be found in relatively pure stands.

The cedar-hardwoods type is composed of mixed stands of eastern red-cedar and hardwoods of all types. Post oak, Blackjack oak, black oak, elm and persimmon are the common hardwood associates.

The bottomland hardwoods type is located along rivers and streams. The type contains mixed stands of sycamore, cottonwood, river birch, willow, bur-oak and pin-oak.

<u>Other Land</u> Farmsteads, wildlife areas and other tracts not classified as cropland, pasture, or woodland.

Table 3 shows the estimated land use distribution by counties for total resource areas in each county.

ESTIMATED LAND USE BY RESOURCE AREA
IN MERAMEC RIVER BASIN

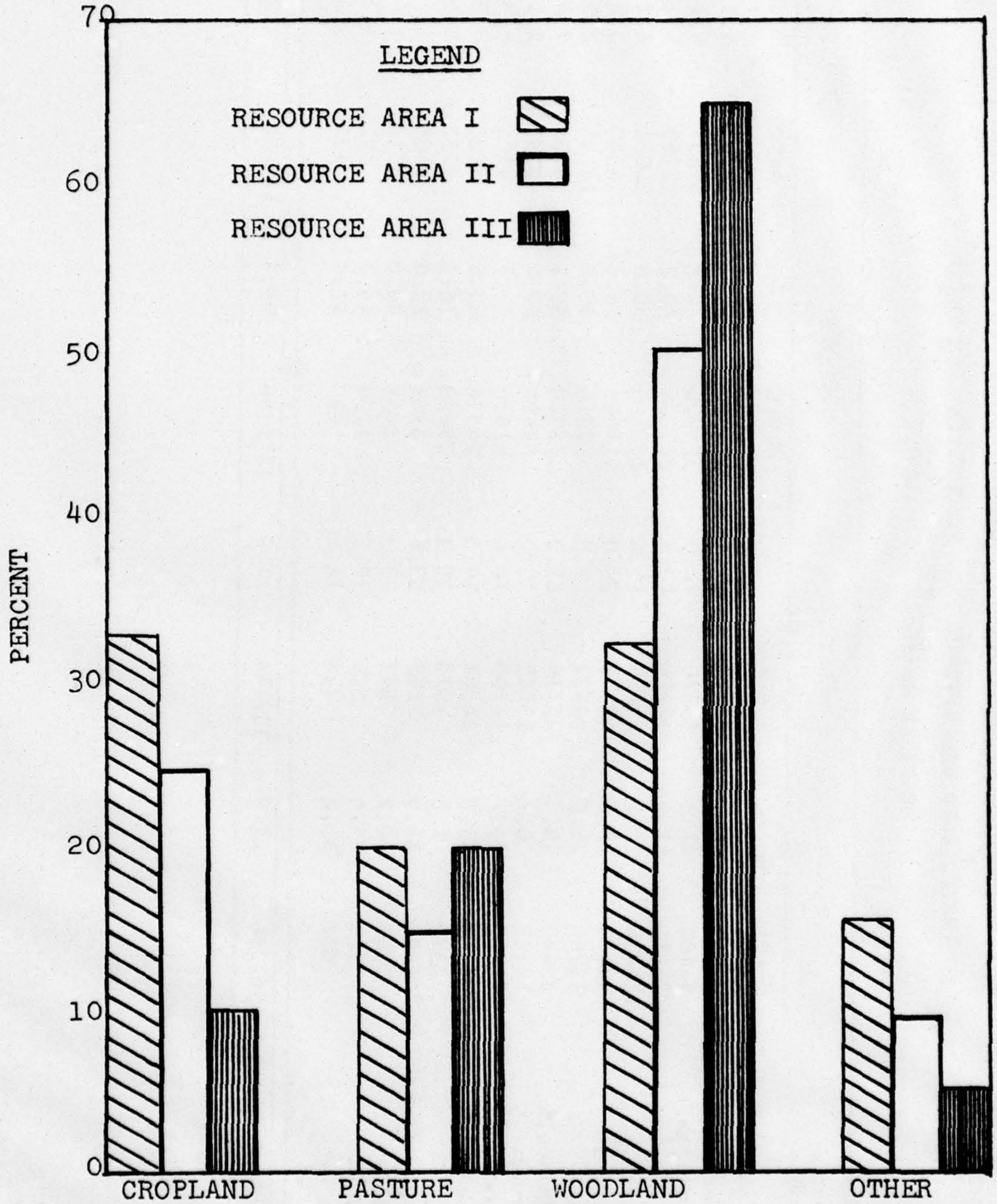


Figure 3

TABLE 3

ESTIMATED LAND USE DISTRIBUTION BY COUNTIES FOR TOTAL RESOURCE AREAS IN EACH COUNTY

County	CROPLAND		PASTURE		WOODLAND		OTHER	
	Acres	%	Acres	%	Acres	%	Acres	%
Crawford	81545	16.8	57334	11.8	324500	66.7	23020	4.7
Washington	54260	11.2	58230	12.0	352600	72.7	19851	4.1
Dent	44111	15.3	29726	10.3	203024	70.2	12163	4.2
Franklin	111424	29.2	55569	14.6	190720	50.0	24034	6.2
Jefferson	39855	18.6	42678	20.0	117066	54.6	14580	6.8
Phelps	55969	31.5	34627	19.5	72314	40.7	14735	8.3
St. Francois	23960	20.5	25714	22.0	58560	50.1	8766	7.4
Gasconade	46155	40.7	15622	13.8	42400	37.4	9231	8.1
St. Louis	56739	56.7	16790	16.8	21660	21.7	4805	4.8
Maries	31143	43.0	10541	14.5	24536	33.9	6228	8.6
Iron	7520	9.6	8070	10.3	59670	76.6	2753	3.5
Ste. Genevieve	6792	31.5	7289	33.9	4969	23.0	2485	11.5
Reynolds	305	4.9	327	5.3	5451	88.0	111	1.8
Texas	969	35.6	328	12.1	1230	45.2	193	7.1
Osage	637	34.2	216	11.6	880	47.4	127	6.8
TOTALS:	561384	22.0	363154	14.0	1479580	58.8	143082	5.2

Conservation Practices

Information obtained from the Soil and Water Conservation Needs Inventory and the Forest Service indicate the following acreage treated and needing treatment for the basin by Resource Areas. Practices included on treated agricultural land include proper rotations and soil treatment, mechanical practices such as terraces, diversions, drainage, and vegetative practices as pasture seeding, and improvement of existing stands of grass. Practices on treated forestland are areas receiving proper protection and cutting practices.

	Treated	Needing Treatment
Resource Area I	45,000 ac.	83,194 ac.
Resource Area II	125,000 ac.	609,595 ac.
Resource Area III	421,000 ac.	1,263,411 ac.

These figures indicate that approximately 25% of the land in the basin is either adequately treated or needs no major conservation treatment. The remaining 75% of the land needs some type of conservation treatment to conserve the soil resource. These estimates are based on the land use in 1959.

Table 4 shows the estimated acres treated and needing treatment by counties.

TABLE 4

ESTIMATED ACRES TREATED AND NEEDING TREATMENT BY COUNTIES

County	Acres Treated *	Acres Needing Treatment
Crawford	121600	364800
Washington	111536	373405
Franklin	99254	282493
Dent	92488	196536
Jefferson	38569	175703
Phelps	63952	113693
St. Francois	30420	86580
Gasconade	20413	92995
St. Louis	34999	64995
Iron	15602	62410
Maries	22459	49989
Ste. Genevieve	4522	17013
Reynolds	1239	4955
Texas	843	1877
Osage	577	1283
TOTALS:	658473	1888727

* Includes such practices as rotations, liming and fertilizing, terracing, drainage, pasture improvement, and proper protection, and cutting on forested lands.

PART 2

Interim Survey Report

HEADWATER "H" RESERVOIRS

MERAMEC RIVER BASIN

Missouri

Prepared Under the Authority of Section 6 of the Watershed Protection and Flood Prevention Act (Public Law 566, 83rd Congress; 68 Stat. 666), as amended.

Prepared by:

U. S. Department of Agriculture
Soil Conservation Service
Forest Service
Economic Research Service

August, 1963

MERAMEC RIVER BASIN

(INTERIM)

HEADWATER "H" RESERVOIRS

MISSOURI

Introduction

This interim report on the headwater reservoirs in the Meramec River Basin was prepared by the Soil Conservation Service, Forest Service, and Economic Research Service of the U. S. Department of Agriculture.

It contains information on engineering studies and cost estimates of the Headwater "H" Reservoirs in locations determined by the Corps of Engineers, St. Louis District. Both sediment and permanent water storage volumes were predetermined by the Corps. (Table 5)

The Department of Agriculture has made no investigations to determine whether or not these sites represent the best alternatives for achieving the objectives for which they were selected, or whether or not, from the standpoints of location, capacity and design, they will fit into an overall comprehensive plan for development of the water and related land resources of the Meramec River Basin. No damage or benefit evaluations of these reservoirs on a single or multiple use basis have been made by the U. S. Department of Agriculture.

Geology of Reservoir Sites

The geologic formations involved in the "H" reservoir sites of Meramec River Basin are the Derby-Doerun, Davis, Potosi, and Eminence of the Upper Cambrian System and the Gasconade, Roubidoux, and Jefferson City of the lower Ordivician System.

The Upper Cambrian Series is made up of medium to massive bedded dolomites with a small amount of chert nodules and angular fragments of chert. Some thin bedded siltstones and shales are found in the Derby-Doerun and some sandstone and angular conglomerate in the Davis.

The rocks of the Ordivician System in the Canadian Series are principally arenaceous and cherty dolomites and sandstones. The Gasconade is characterized by the large amount of chert as well as frequent caves and springs. The Roubidoux consists of sandstones, dolomitic sandstones and cherty dolomites.

The rock formations at all of the "H" dam sites are similar in their aspect of bedding, firmness and attitude. Although some of the formations have variations in the amounts of shale, dolomite, or sandstone, there are no significant variations in their ability to support an earthen dam. The bedding of the various formations is equally similar in that the beds are medium to massive, generally continuous, and generally tight. The attitude of the beds is essentially horizontal. Some faults exist in the reservoir areas but faulting has not been observed near the dam sites.

Geologic Investigations

The surface geology of each of twelve (12) structural sites selected by the U. S. Army Corps of Engineers, was investigated.

Sites H-13, H-5, H-3, and H-31 are located in the Jefferson City formation with the valleys and reservoir areas cutting into the Roubidoux. These sites present no particular problem from a water holding and construction standpoint.

Sites H-6, H-10 and H-11 were in areas of the Roubidoux formation with the valleys and reservoir areas encised into the Gasconade formation.

The Gasconade formation shows evidence of serious solution channeling. The center lines for structure sites H-10 and H-11 were moved upstream to secure the better water holding capabilities of the Roubidoux formation. The new sites were designated H-10A and H-11A. Alternate sites for structure H-6 present the same, or some other construction problem of equal or greater magnitude. The center line location for H-6 was not changed. The critical geologic factors of site H-6 were taken into account in the designs which allow for blanketing of exposed outcrops of the Gasconade formation, not disturbing overburden in the reservoir bottom and grouting of the foundation and abutments, if necessary.

Sites H-8 and H-9 have their valley floor and abutments in the Eminence formation. The uplands of their drainage areas are in the Gasconade formation. Sites H-8 and H-9 present no serious problems from the standpoint of water holding capabilities and construction materials.

Sites H-4, H-25 and H-40 are in the Derby-Doerun and Davis formation of the Elvins group. The sites are characterized by steep massive rock outcrops on both abutments. Although these sites present no serious problems from a water holding standpoint, there is a likelihood of having long hauls for earth fill material.

HYDROLOGIC AND HYDRAULIC INVESTIGATIONS

Runoff

The runoff characteristics of each individual site were determined and evaluated to establish design runoff curve numbers. The 50-year frequency point rainfall amounts, as shown in U. S. Weather Bureau Technical Paper No. 40, were theoretically applied to the watersheds to develop an accumulated runoff curve for each site.

Release Rates

Downstream channel capacities and conditions were investigated. Release rates were chosen that approximated one-half of channel capacity immediately below the structure. This rate was then adjusted to provide draw-down of the flood detention pools within a three (3) to six (6) day period.

Stage/Storage Curves

Standard average-end-area methods were used to compute stage/storage information for the six (6) sites surveyed. Since less time consuming means of establishing stage/storage information for planning purposes was desired, stage/storage curves for the six (6) surveyed sites were also developed by planimetering enlargements of U. S. Geological Survey contour maps. Comparing the stage/storage information obtained by the two methods, it was felt that the second method was acceptable. Stage storage information for the six (6) remaining sites was therefore obtained from U. S. Geological Survey contour map enlargements.

Design Storm Durations

Storm durations producing maximum flood storage requirements were obtained by graphically combining the accumulated runoff curve and the accumulated release curve. Storm durations obtained in this manner varied from 1.5 to 3.1 days with rainfall amounts from 7.10 to 8.50 inches producing runoffs from 3.44 to 5.42 inches. Auxiliary emergency spillway elevations were chosen to provide this amount of storage, above the permanent pool, less the amount released through the principal spillway during this period.

Design Hydrographs

Design hydrographs, developed according to Central Technical Unit procedures, were flood routed through the reservoirs by Graphical Method 2 (as presented in Section 4 of the S. C. S. National Engineering Handbook) to determine elevation and size of the auxiliary spillways and required height of dam. The emergency (auxiliary) spillways were designed according to Soil Conservation Service requirements for Class b structures.

ENGINEERING INVESTIGATIONS

Site Investigations

Each site was investigated with regard to providing the best storage to fill volume ratio available in the area, availability of construction material, and economical location of auxiliary spillways. Site H-13 was moved approximately three fourths (3/4) of a mile downstream and the location of site H-5 was moved upstream approximately 700 feet to secure a more favorable ratio of storage to fill volume.

The remaining ten (10) structure sites were adjudged to be the best available in the general area of the original locations.

Survey Procedures

Six (6) representative sites were chosen for field survey. These included (1) rocky gorge with steep abutments, (2) wide floodplain with steep rocky abutments, (3) gently sloping abutments from a narrow valley floor, and (4) combinations of the above. On these six (6) sites, valley cross-sections were obtained by stadia at the embankment center lines, the wide and narrow points of the valley, and across major side drainages in the storage pool area. These cross-sections were obtained by stadia survey and referenced to a base line established by an exterior angle route survey. Vertical control was from temporary bench marks of assumed elevation. Horizontal control was by azimuth bearings computed from measured exterior angles and referenced to approximated azimuth bearing (compass azimuth) of the embankment centerlines.

Valley cross-sections of the embankment centerline of the remaining six (6) sites were obtained by stadia survey for purposes of computing fill volume.

No attempt was made, in the field, to tie elevations at these sur veys to established U. S. Geological Survey bench marks. The cross sections were located on U. S. G. S. topographic maps in the office to establish the sea level datum for the surveys.

Design Criteria

With one major exception, the design of structures was based on criteria set forth in Engineering Memorandum SCS-27, "Limiting Criteria for Design of Earth Dams", sub-section 3.10 and 3.21 of S. C. S. National Engineering Handbook, Section 4. The major exception mentioned above was in establishing the size of a permanent pool. Storage volume of the permanent pools for the "H" reservoirs was determined by the Corps of Engineers prior to our participation in the Meramec Basin studies. These permanent pool areas had already been evaluated, for various purposes, by other interested agencies, therefore we were requested to design these reservoirs with storage volumes approximately the same as that set forth for other agencies. Design storage volumes are within five (5) percent of that previously set forth by the Corps.

Standard excavated earth auxiliary spillways were designed for structure sites H-3, H-5A, H-6, H-8, H-9, H-11A, H-13A and H-31. Structure H-8 design included a compacted "earth ramp" type emergency spillway and site H-6 design included an emergency spillway excavated through the rock abutment.

Structures for sites H-4, H-10A, H-25 and H-40 were designed with concrete chute type emergency spillways.

With the exception of site H-40, all sites provide flood storage to control 50-year frequency runoffs, with draw-down through single stage ungated drop inlets to reinforced concrete pipe or monolithoc concrete box outlet barrels.

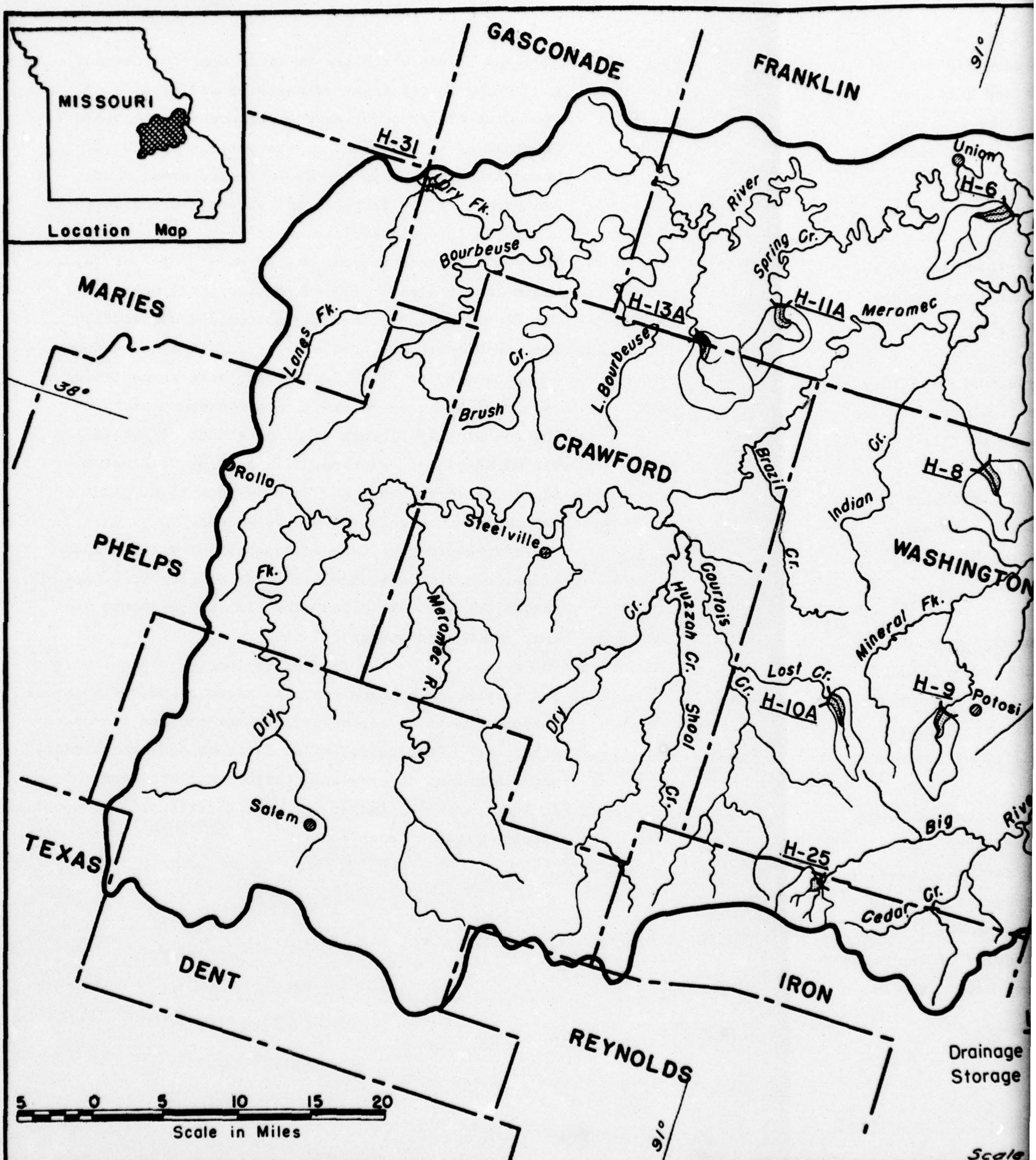
Site H-40 design provides for a single overflow type chute spillway. This type of spillway was chosen to keep the shoreline fluctuation to a minimum. No flood retardation was included in the design of this structure, as specified by the Corps.

Estimated volumes of concretes in the chute type spillways were obtained by extrapolating information contained in Drawing E S 87 and Figure 2 of Soil Conservation Service National Engineering Handbook, Section 14.

Cost Estimates

Construction costs were computed on the basis of average unit prices compiled from recent contracts of P. L. 566 projects in Missouri, and suppliers list prices. Unit prices were adjusted to reflect remoteness of site, availability of construction material, haul distances, size of work area, quantity variance from the norm and availability of trained construction workers.

Total cost includes contract costs, construction contingencies, engineering overhead, administrative overhead, relocations and land cost. (Table 6) A smaller contingency allocation was allowed for structures H-5A, H-13A and H-31 since the sub-surface geology of these sites could be predicted with more certainty than for the remaining nine (9) structures. Land easement costs vary with geographical area and intensity of improvements thereon, and reflect present day real estate values within the basin.



MISSOURI
Location Map
GASCONADE
FRANKLIN
MARIES
PHELPS
TEXAS
DENT
REYNOLDS
IRON
CRAWFORD
WASHINGTON
H-31
H-6
H-13A
H-11A
H-8
H-9
H-10A
H-25
Union
Rolla
Steelville
Salem
Potosi
Bourbeuse
River
Spring Cr.
Meromec
Lanes Fk.
Brush Cr.
L. Bourbeuse
Brazil Cr.
Indian Cr.
Courtois
Huzzah Cr.
Shoal Cr.
Meromec R.
Mineral Fk.
Lost Cr.
Big River
Cedar Cr.
Dry Fk.
Dry Cr.
Fk.
38°
91°
Drainage
Storage
5 0 5 10 15 20
Scale in Miles
Scale

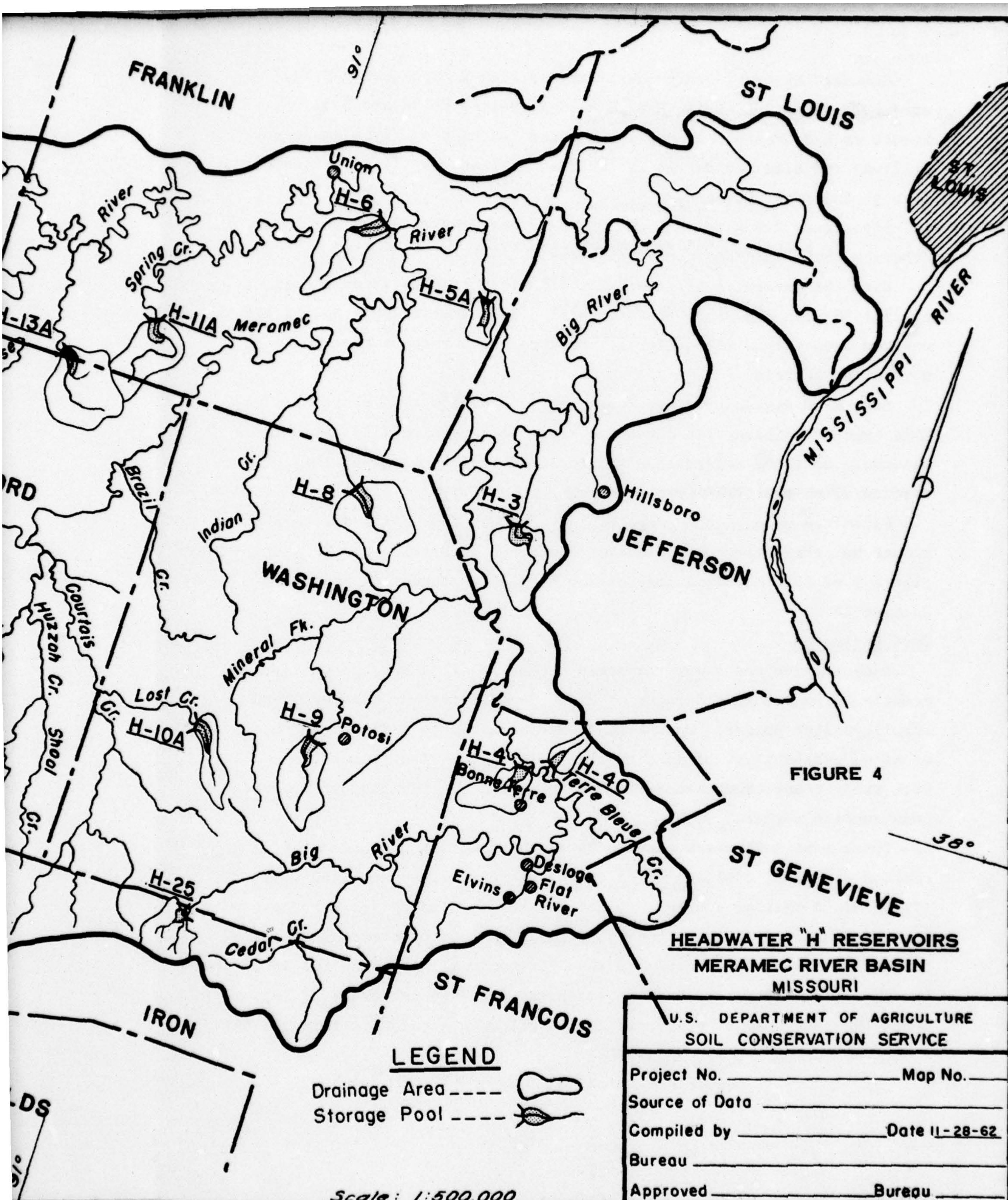


FIGURE 4

HEADWATER "H" RESERVOIRS
MERAMEC RIVER BASIN
MISSOURI

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Project No. ______ Map No. ______
Source of Data ______
Compiled by ______ Date 11-28-62
Bureau ______
Approved ______ Bureau ______

2

TABLE 5

STRUCTURE DATA

HEADWATER (H) RESERVOIRS

MERAMEC BASIN, MISSOURI

ITEM	UNIT	H-3	H-4	H-5	H-6	H-8	H-9
Drainage Area							
Acres		5,900	5,230	1,984	6,660	11,410	5,115
Square Miles		9.22	8.17	3.10	10.41	17.82	8.00
Storage Capacity							
Sediment 5/	ac. ft.	899	880	306	972	1,390	810
Floodwater	ac. ft.	1,850	1,197	645	1,790	4,565	1,432
Total	ac. ft.	2,749	2,077	951	2,762	5,955	2,242
Surface Area							
Sediment Pool	ac.	102.5	49.0	40.0	104.6	117.0	75.0
Floodwater Pool	ac.	210.0	92.7	68.5	238.0	292.0	146.3
Volume of Fill	cu. yds.	89,000	228,379	103,249	168,012	360,284	155,262
Elevation Top of Dam 1/	ft.	635.0	683.0	554.6	542.6	725.5	955.0
Maximum Height of Dam	ft.	43.0	66.0	42.6	50.6	61.5	47.0
Emergency Spillway							
Crest Elevation	ft.	629.0	673.0	549.2	536.0	717.5	948.0
Bottom Width	ft.	185	162	92	75	200	140
Type		Earth	Chute	Earth	Rock	Ramp	Earth
Percent chance of use		2	2	2	2	1	2
Ave. Curve No. - Cond. II		79	73	78	81	76	72
Emergency Spillway Hydrograph							
Storm rainfall (6-hr.)	in.	7.90	7.90	7.88	7.88	7.62	7.97
Storm runoff	in.	5.42	4.73	5.29	5.62	4.82	4.67
Velocity of flow (V_c) 2/	ft./sec.	6.5	6.0	5.5	7.0	0	6.5
Discharge rate 2/	c.f.s.	1,615	1,108	550	820	0	1,180
Max. w. s. elev. 2/	ft.	632.0	674.7	551.0	538.8	716.2	950.4
Freeboard hydrograph							
Storm rainfall (6-hr.)	in.	14.00	14.09	14.00	13.92	13.46	14.14
Storm runoff	in.	11.25	10.46	11.11	11.45	10.29	10.35
Velocity of flow (V_c) 2/	ft./sec.	11.7	12.5	10.3	11.6	13.5	12.0
Discharge rate 2/	c.f.s.	9,600	10,000	3,345	4,400	17,200	7,800
Max. w. s. elev. 2/	ft.	635.0	682.0	554.6	542.6	722.8	955.0
Principal Spillway							
Capacity 3/	c.f.s.	205	212	75	375	428	196
Capacity Equivalents							
Sediment volume 5/	in.	1.83	2.02	1.85	1.75	1.46	1.90
Detention volume	in.	3.76	2.75	3.90	3.55	4.80	3.36
Spillway storage	in.	2.44	2.37	2.80	5.28	2.62	2.72
Class of Structure 6/		B	B	B	B	B	B

1/ Survey elevations not referenced to U.S.G.S. Bench Marks but related to elevations on U.S.G.S. topog

2/ Maximum during passage of hydrograph.

3/ No provision for floodwater detention.

4/ Overflow type spillway is the only outlet.

5/ Amount to be stored specified by U. S. Army Corps of Engineers.

6/ All structures of damage hazard class "a", but hydrologic criteria for structure class "b" was used

/

TABLE 5

STRUCTURE DATA

HEADWATER (H) RESERVOIRS

MERAMEC BASIN, MISSOURI

	H-5	H-6	H-8	H-9	H-10	H-11	H-13	H-25	H-31	H-40	TOTAL
D	1,984	6,660	11,410	5,115	2,707	6,784	13,470	8,525	3,987	2,517	74,229
7	3.10	10.41	17.82	8.00	4.23	10.64	21.05	13.32	6.23	3.94	116.13
D	306	972	1,390	810	572	1,165	1,405	1,210	600	900	11,109
7	645	1,790	4,565	1,432	665	1,883	4,170	1,448	1,160	3/	20,120
7	951	2,762	5,955	2,242	1,237	3,048	5,575	2,658	1,760	900	31,229
0	40.0	104.6	117.0	75.0	55.0	103.2	138.5	87.3	67.5	51.5	991.1
7	68.5	238.0	292.0	146.3	86.8	198.0	335.0	142.0	137.5	3/	1925.1
9	103,249	168,012	360,284	155,262	137,996	129,037	240,164	79,640	170,482	144,277	1,971,994
0	554.6	542.6	725.5	955.0	1015.4	824.0	817.5	1054.0	894.5	685.0	XXXXXX
0	42.6	50.6	61.5	47.0	47.4	48.0	53.5	66.0	44.4	53.1	XXXXXX
0	549.2	536.0	717.5	948.0	1006.4	818.0	810.7	1043.8	888.1	674.6	XXXXXX
2	92	75	200	140	75	180	250	90	135	90	XXXXXX
e	Earth	Rock	Ramp	Earth	Chute	Earth	Earth	Chute	Earth	Chute4/	
2	2	2	1	2	2	2	2	2	2	2	XXXXXX
3	78	81	76	72	66	75	76	62	78	67	XXXXXX
0	7.88	7.88	7.62	7.97	8.00	7.93	7.50	7.86	8.03	7.91	XXXXXX
3	5.29	5.62	4.82	4.67	4.01	4.98	4.71	3.45	5.43	4.05	XXXXXX
0	5.5	7.0	0	6.5	5.5	6.2	5.0	0	7.7	4.1	XXXXXX
8	550	820	0	1,180	375	1,342	700	0	780	199	XXXXXX
7	551.0	538.8	716.2	950.4	1008.1	819.8	812.3	1043.8	891.3	675.4	XXXXXX
9	14.00	13.92	13.46	14.14	14.25	14.00	13.40	13.96	14.09	14.09	XXXXXX
6	11.11	11.45	10.29	10.35	9.52	10.60	10.24	8.60	11.20	9.53	XXXXXX
5	10.3	11.6	13.5	12.0	11.7	11.8	11.7	10.2	11.4	8.6	XXXXXX
0	3,345	4,400	17,200	7,800	3,775	9,400	13,500	6,620	6,500	5,775	XXXXXX
0	554.6	542.6	722.8	955.0	1014.2	824.0	817.5	1052.5	894.5	683.5	XXXXXX
2	75	375	428	196	75	293	493	302	184	5,775 4/	XXXXXX
2	1.85	1.75	1.46	1.90	2.57	2.06	1.25	1.70	1.81	4.29	XXXXXX
5	3.90	3.55	4.80	3.36	2.95	3.34	2.54	2.04	3.49	3/	XXXXXX
7	2.80	5.28	2.62	2.72	3.46	2.27	2.44	2.02	3.04	2.70	XXXXXX
B	B	B	B	B	B	B	B	B	B	B	

ks but related to elevations on U.S.G.S. topographic sheets.

gineers.

gic criteria for structure class "b" was used in the designs.

August,1963

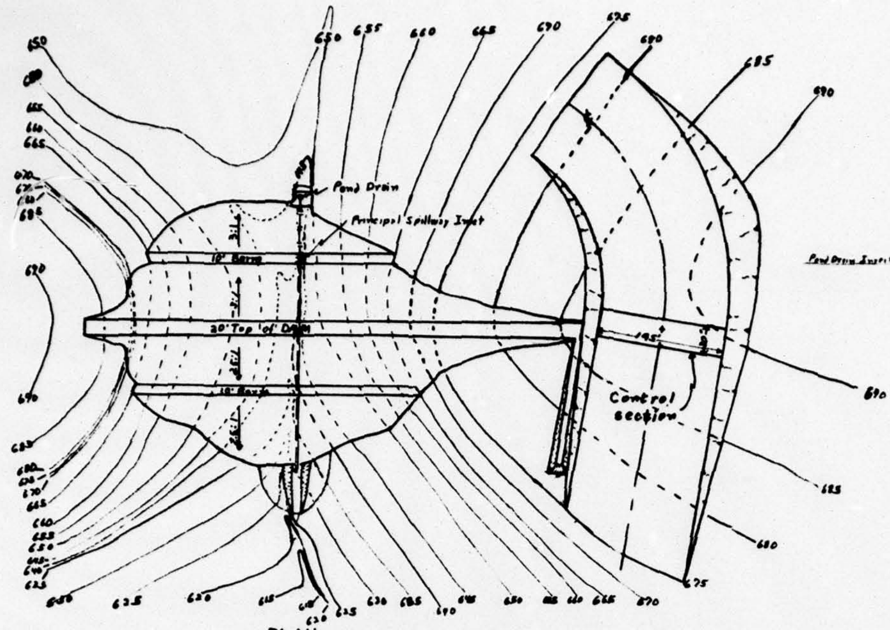
2

TABLE 6
ESTIMATED STRUCTURAL COST DISTRIBUTION
HEADWATER "H" RESERVOIRS
MERAMEC BASIN, MISSOURI
(DOLLARS) 1/

Structure Number	Construction: Engineers Estimate	Construction: Contin-gencies 2/	Engineering and other 3/	Land Cost 4/	Roads Bridges Utilities 5/	Total Structure Cost
(1)	(2)	(3)	(4)	(5)	(6)	(7)
H-3	66,696	8,004	36,246	66,000	800	177,746
H-4	234,194	28,103	90,574	75,000	5,400	433,271
H-5A	62,487	6,249	23,735	35,000	6,000	133,471
H-6	223,099	26,772	86,284	112,500	9,200	457,855
H-8	193,874	23,265	74,981	141,000	3,600	436,720
H-9	132,671	15,921	51,311	60,000	1,500	261,403
H-10A	120,955	14,515	46,750	33,500	7,000	222,720
H-11A	85,873	10,305	33,212	89,700	500	219,590
H-13A	163,071	16,307	61,942	158,000	2,750	402,070
H-25	170,306	20,437	65,866	67,500	8,000	332,109
H-31	109,408	10,941	41,558	60,000	9,200	231,107
H-40	130,160	15,619	50,339	22,500	3,000	221,618
TOTALS:	1,692,794	196,438	662,798	920,700	56,950	3,529,680

1/ Price based on summary of recent operations contracts under PL-566.
2/ Twelve (12) percent contingencies used where sub-surface geologic conditions not entirely predictable - otherwise ten (10) percent used.
3/ In addition to engineering costs, includes administrative overhead, site drilling and exploration.
4/ Based on prevailing present day real estate values.
5/ Based on interview of county officials.

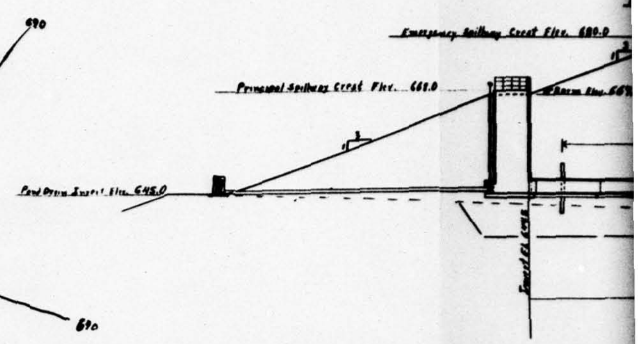
August, 1963

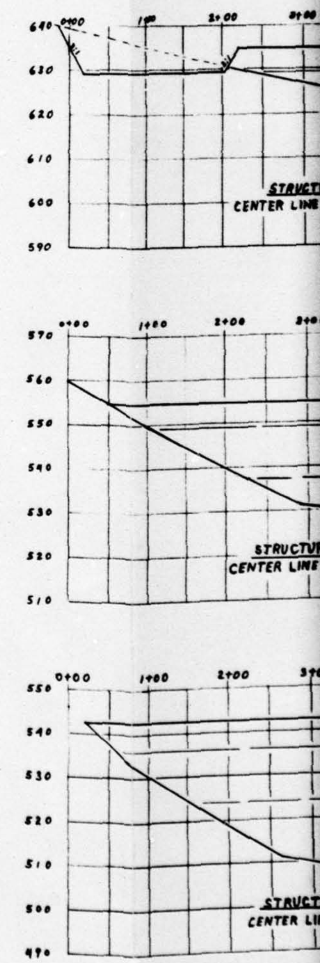


PLAN

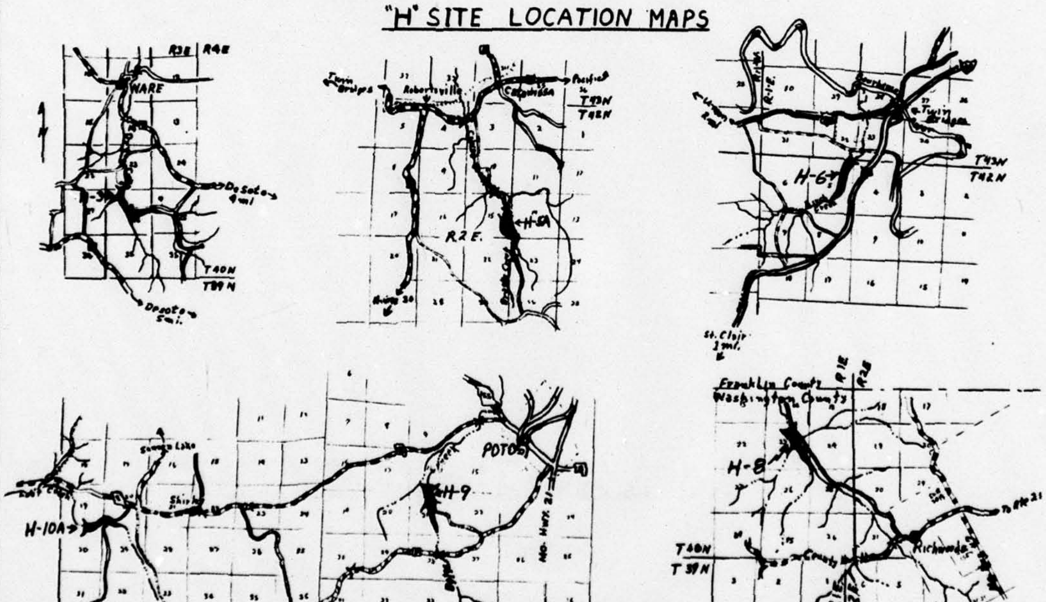
TYPICAL LAYOUT

SCALE IN FEET

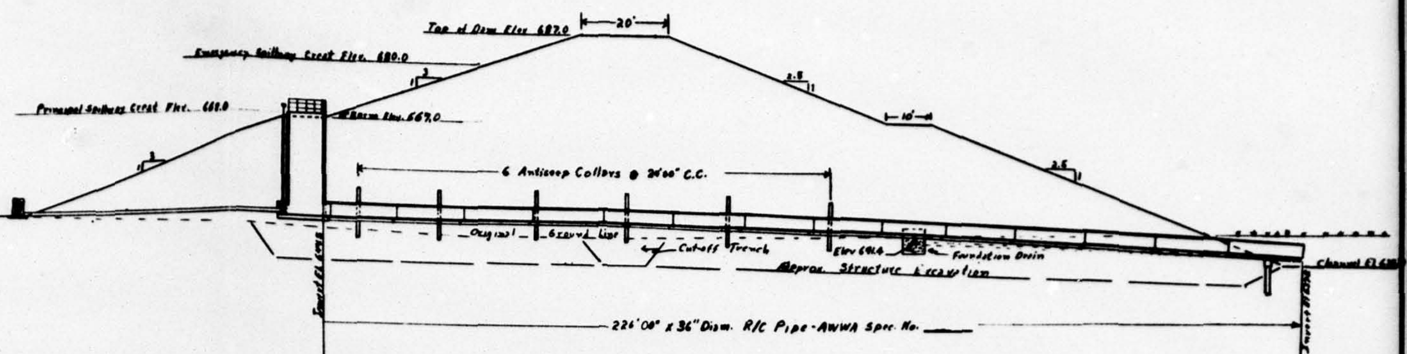




"H" SITE LOCATION MAPS

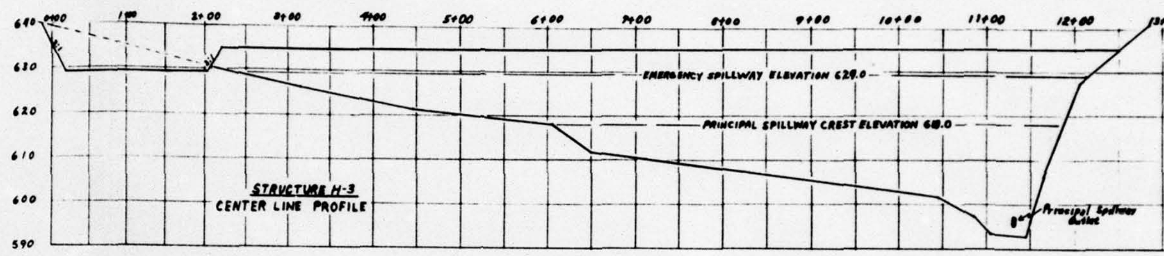


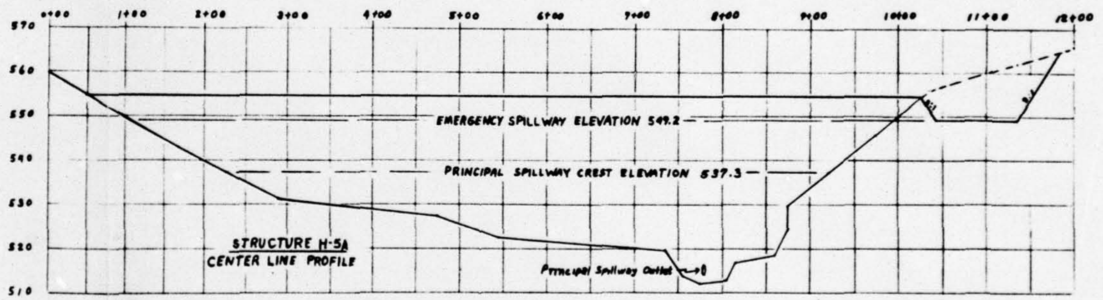
NOTE: Center line profiles fo

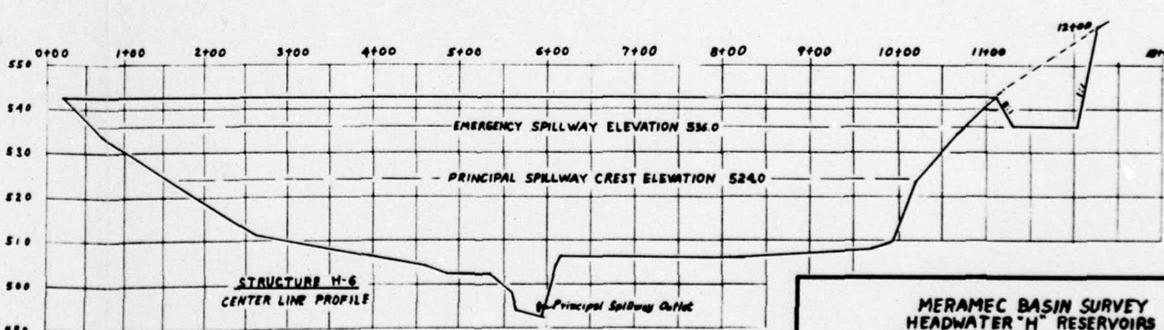


TYPICAL X-SECTION ALONG CENTER LINE OF PRINCIPAL SPILLWAY

SCALE IN FEET







NOTE: Center line profiles for structures H-8, H-9, H-11A, H-13A and H-31 shown on sheet 2 of 3.

MERAMEC BASIN SURVEY
HEADWATER "H" RESERVOIRS
EARTH SPILLWAY TYPE
(STRUCTURES H-3, H-5A, H-6, H-8, H-9, H-11A, H-13A and H-31)

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed	Date	Approved by
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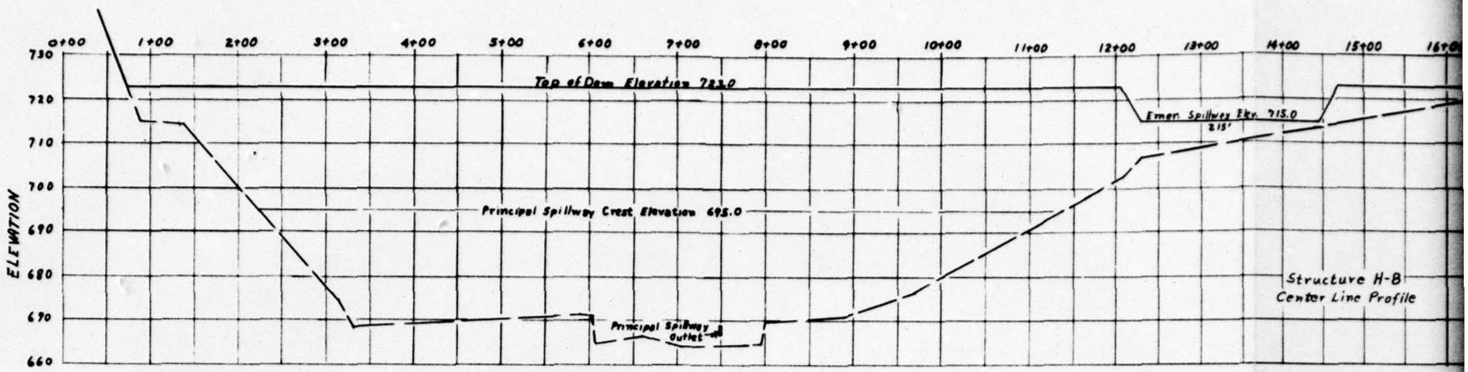
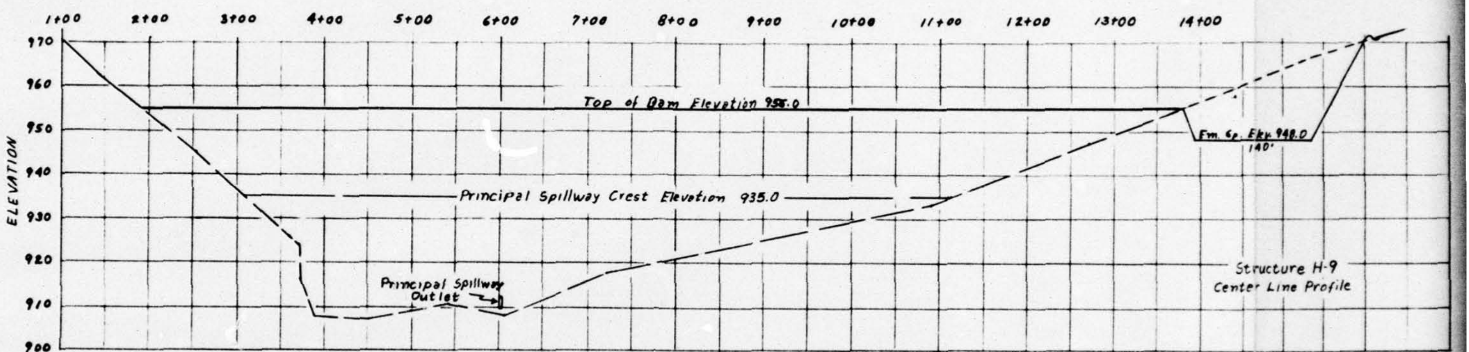
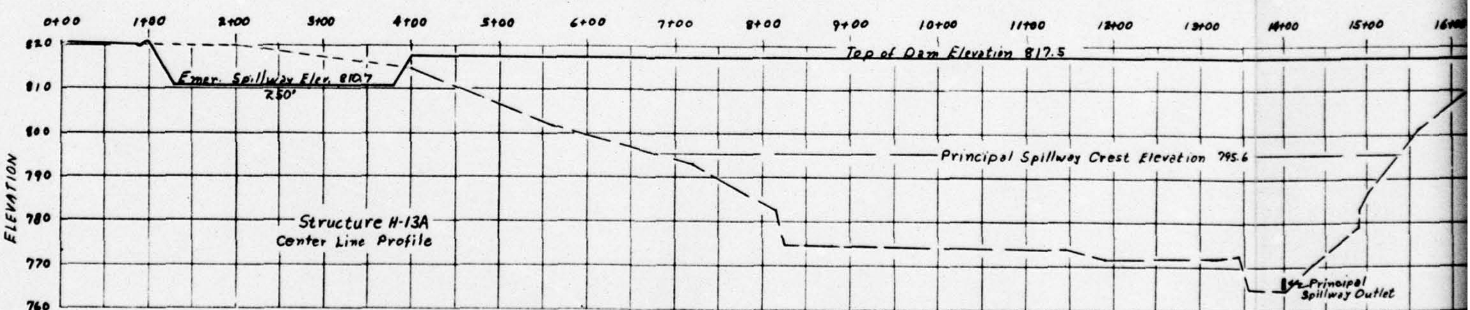
Drawn		
KGR	5-63	Title
Traced		Sheet No. 1 of 3
Checked		Drawing No.



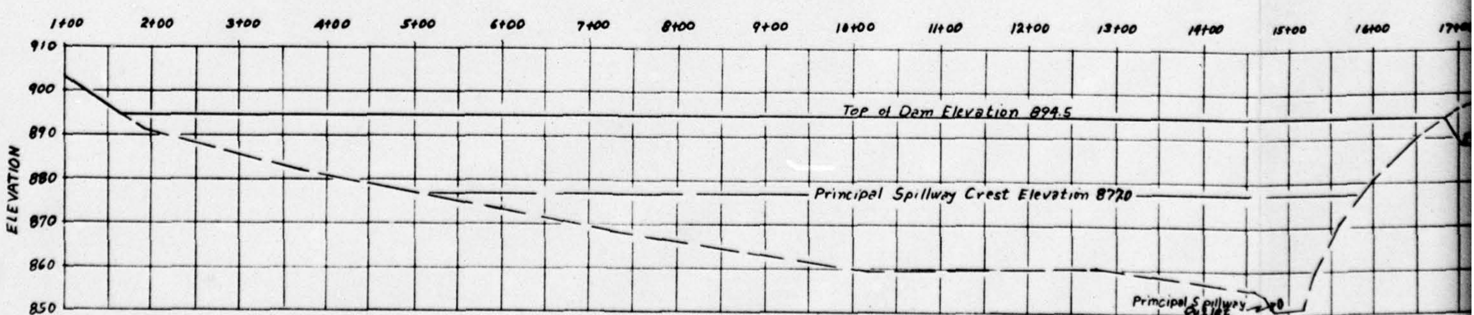
Top of Dam Elevation 723.0
Emer. Spillway Elev. 715.0
215'
Principal Spillway Crest Elevation 695.0
Principal Spillway Outlet
ELEVATION
Structure H-8
Center Line Profile



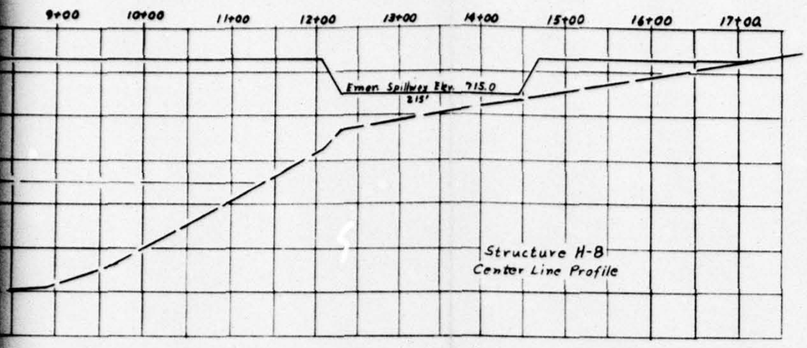
Top of Dam Elevation 955.0
Em. Sp. Elev. 948.0
140'
Principal Spillway Crest Elevation 935.0
Principal Spillway Outlet
ELEVATION
Structure H-9
Center Line Profile

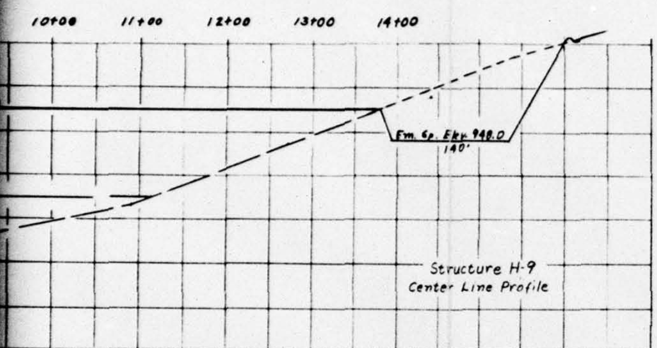


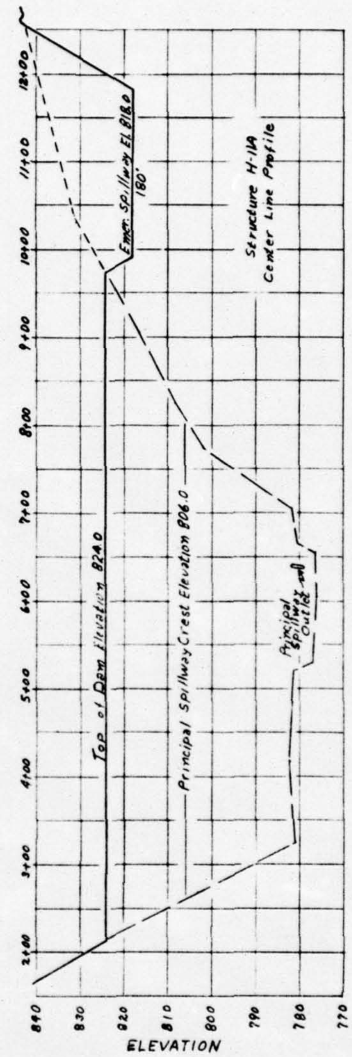
Top of Dam Elevation 817.5
Emer. Spillway Elev. 810.7
750'
Principal Spillway Crest Elevation 795.6
ELEVATION
Structure H-13A
Center Line Profile
Principal Spillway Outlet

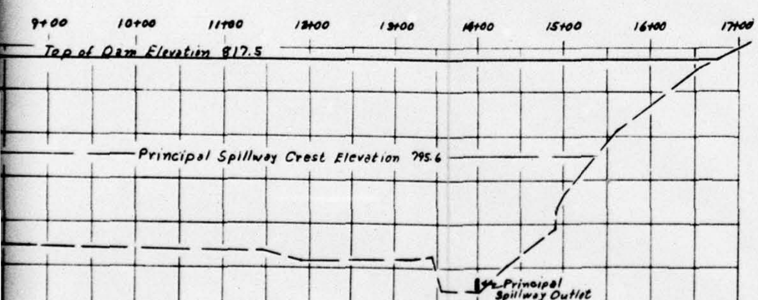


Top of Dam Elevation 894.5
Principal Spillway Crest Elevation 877.0
ELEVATION
Principal Spillway Outlet

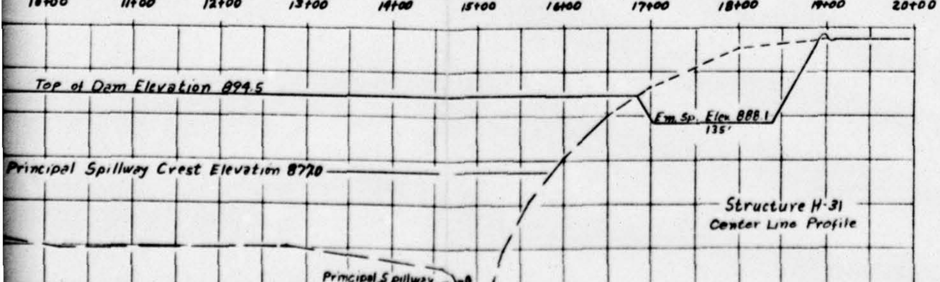








NOTE: Center Line Profiles for Structures H-3, H-5A and H-6 shown on Sheet 1 of 3.

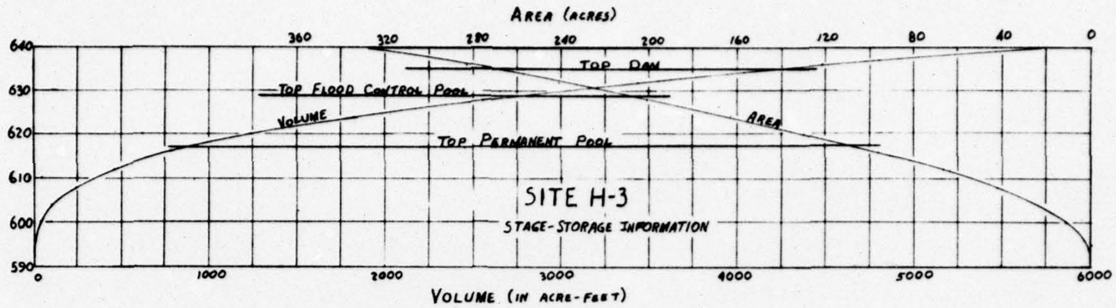


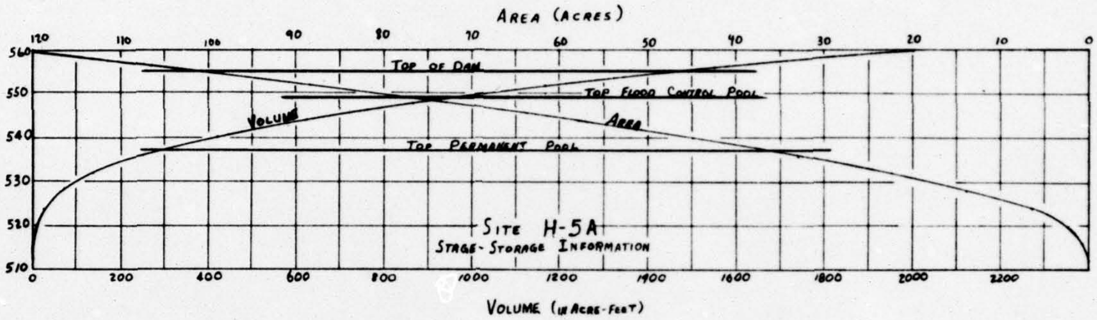
MERAMEC BASIN SURVEY
HEADWATER "H" RESERVOIRS
EARTH SPILLWAY TYPE
(STRUCTURES H-3, H-5A, H-6, H-8, H-9, H-11A, H-13A and H-31)

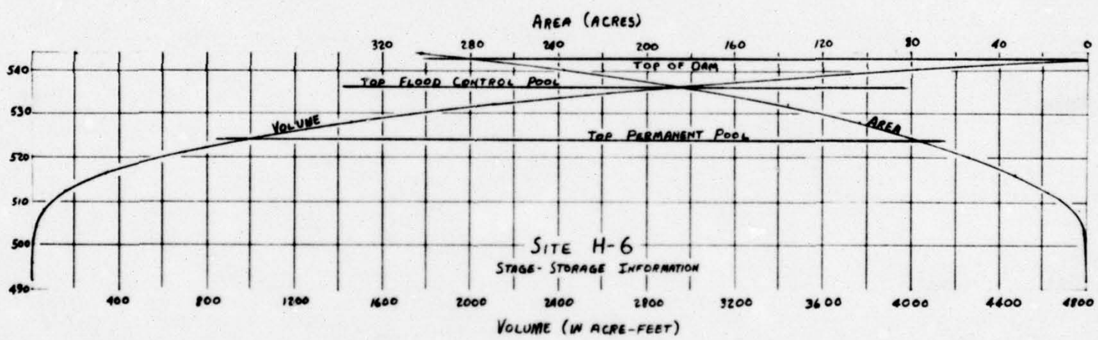
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

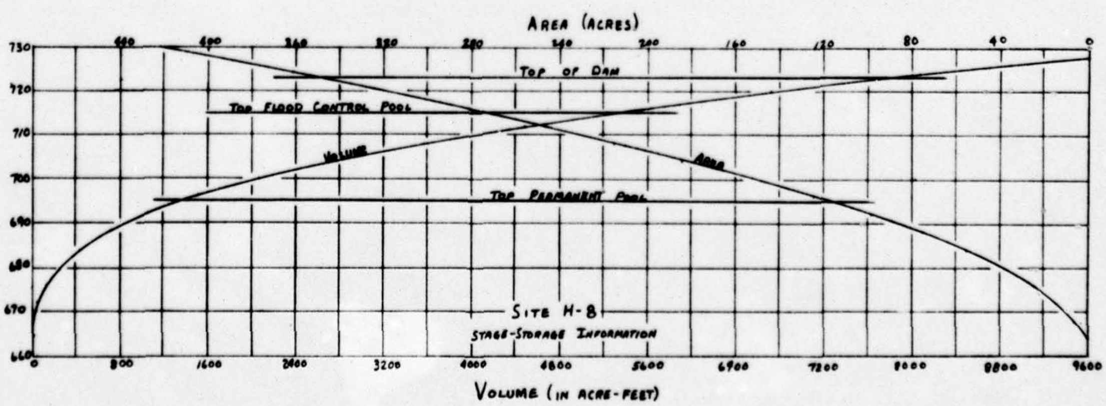
Designed KGA	Date 4-63	Approved by	
Drawn KGB	5-63	Title	
Traced		Title	
Checked		Sheet No. 2 of 3	Drawing No.

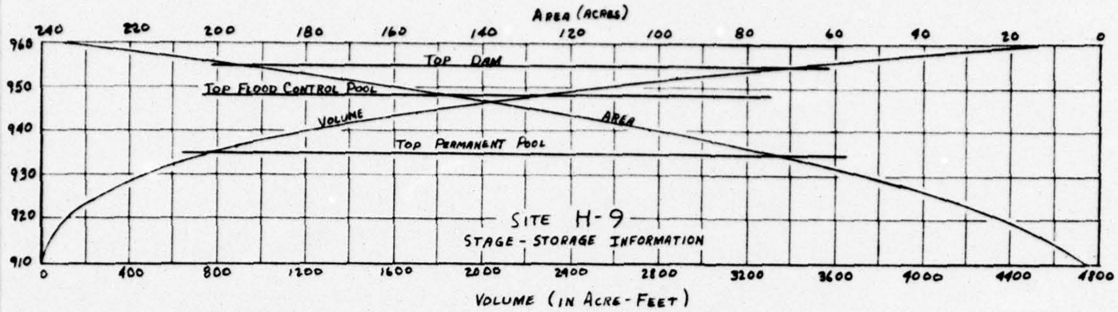
2

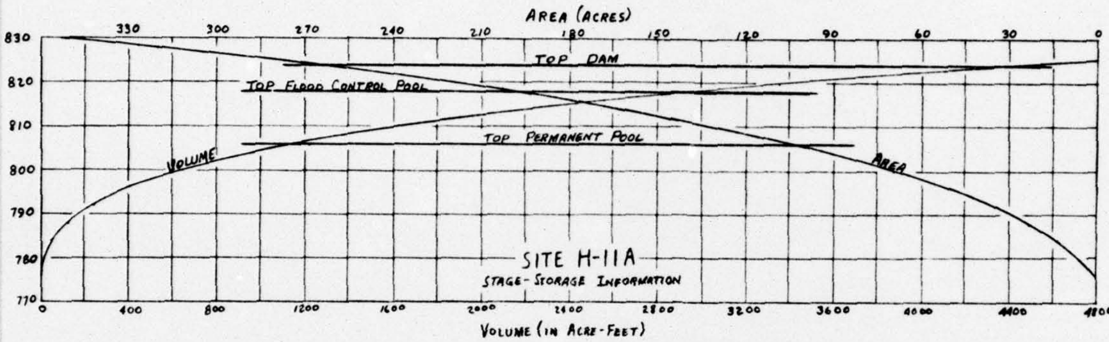

AREA (ACRES)
360 320 280 240 200 160 120 80 40 0
640 630 620 610 600 590
TOP DAM
TOP FLOOD CONTROL POOL
VOLUME
AREA
TOP PERMANENT POOL
SITE H-3
STAGE-STORAGE INFORMATION
0 1000 2000 3000 4000 5000 6000
VOLUME (IN ACRE-FEET)

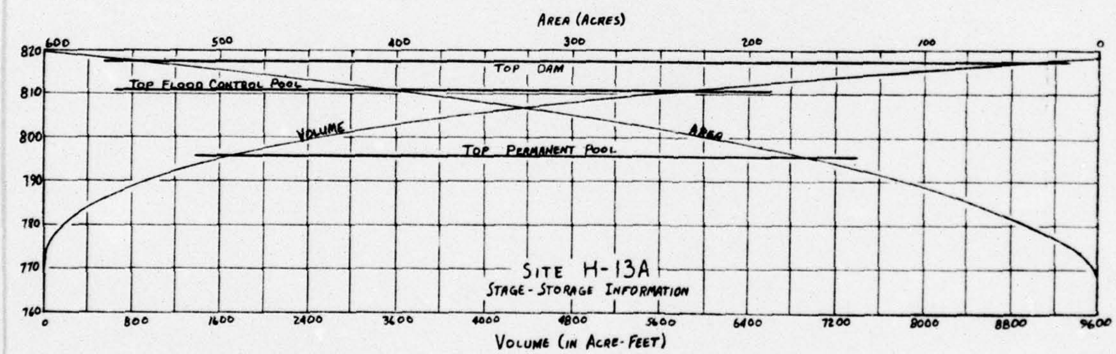

AREA (ACRES)
120 110 100 90 80 70 60 50 40 30 20 10 0
560 550 540 530 520 510
TOP OF DAM
TOP FLOOD CONTROL POOL
VOLUME
AREA
TOP PERMANENT POOL
SITE H-5A
STAGE-STORAGE INFORMATION
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200
VOLUME (IN ACRE-FEET)

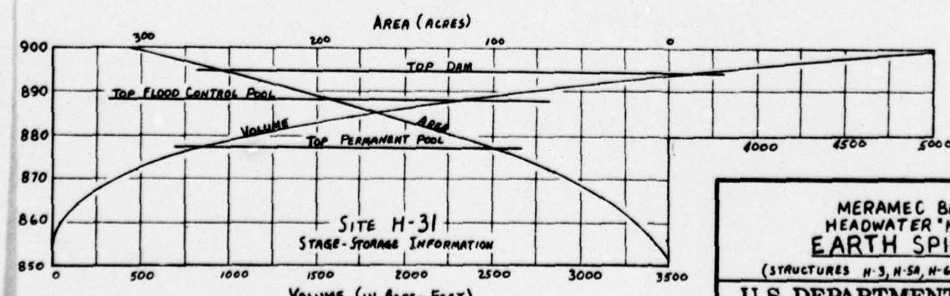

AREA (ACRES)
320 280 240 200 160 120 80 40 0
540 530 520 510 500 490
TOP OF DAM
TOP FLOOD CONTROL POOL
VOLUME
AREA
TOP PERMANENT POOL
SITE H-6
STAGE-STORAGE INFORMATION
400 800 1200 1600 2000 2400 2800 3200 3600 4000 4400 4800
VOLUME (IN ACRE-FEET)


AREA (ACRES)
440 400 360 320 280 240 200 160 120 80 40 0
730 720 710 700 690 680 670 660
TOP OF DAM
TOP FLOOD CONTROL POOL
VOLUME
AREA
TOP PERMANENT POOL
SITE H-8
STAGE-STORAGE INFORMATION
0 800 1600 2400 3200 4000 4800 5600 6400 7200 8000 8800 9600
VOLUME (IN ACRE-FEET)









MERAMEC BASIN SURVEY
HEADWATER "H" RESERVOIRS
EARTH SPILLWAY TYPE
(STRUCTURES H-3, H-5A, H-6, H-8, H-9, H-11A, H-13A and H-31)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed	Date	Approved by
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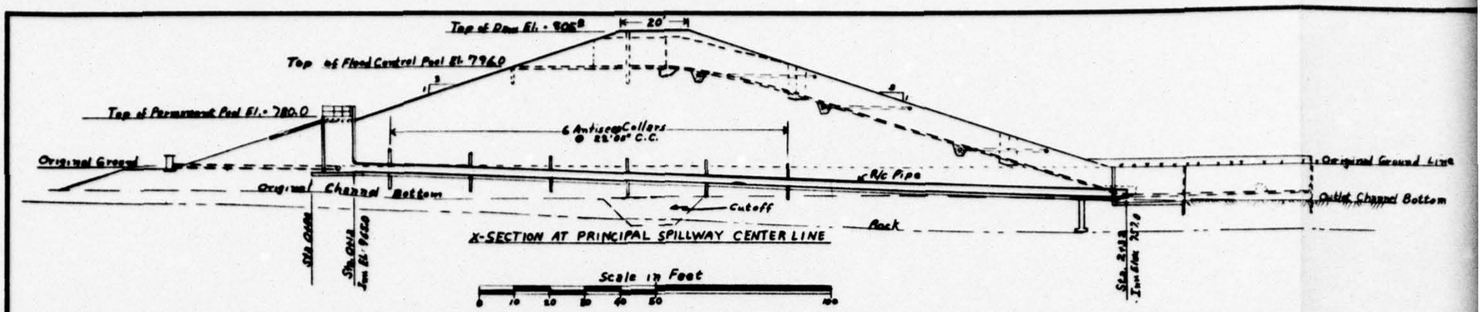
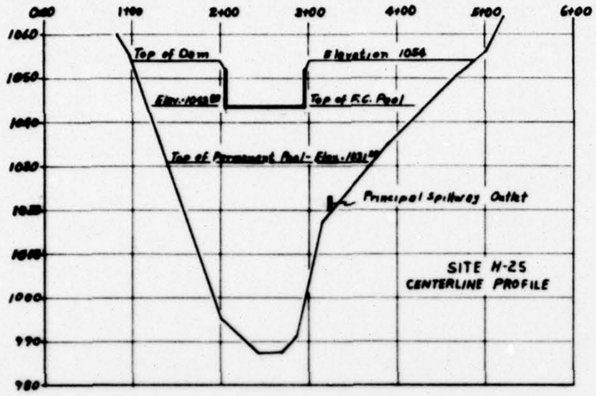
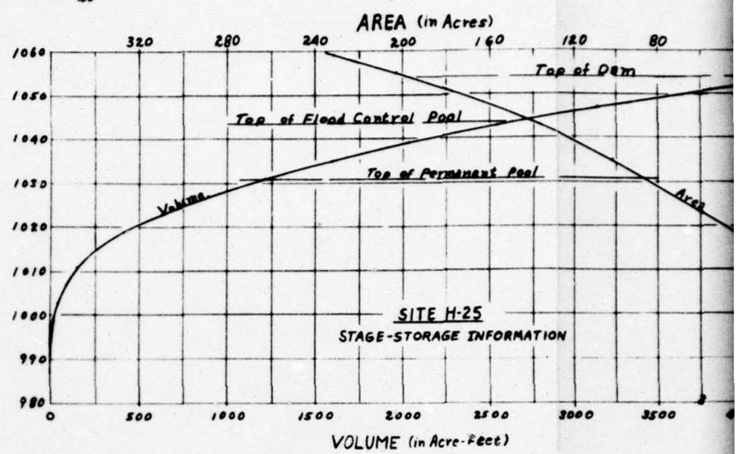
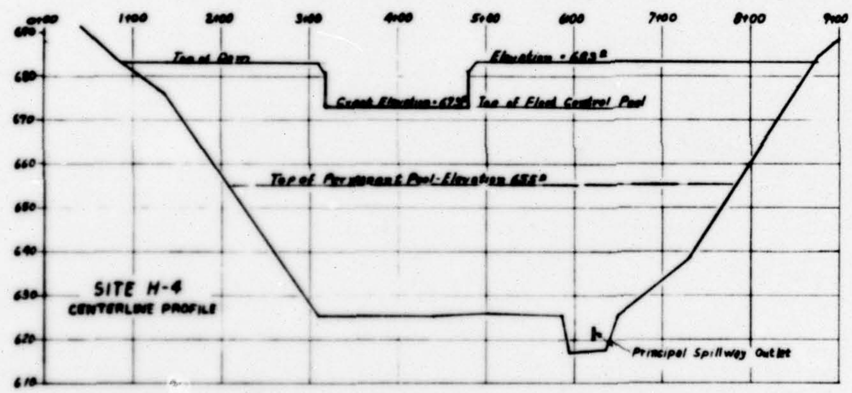
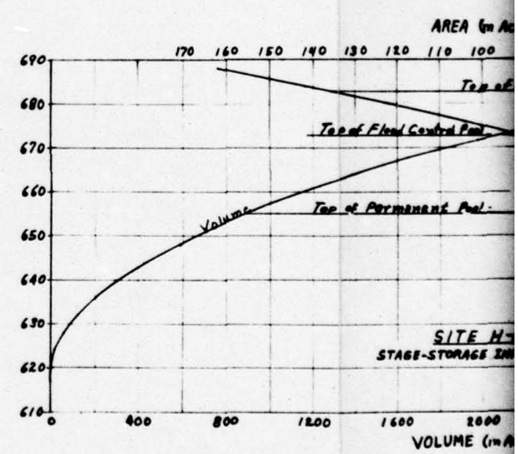
Drawn		
KLW	5-63	Title
Traced		
Checked		Sheet No 3 of 3 / Drawing No.

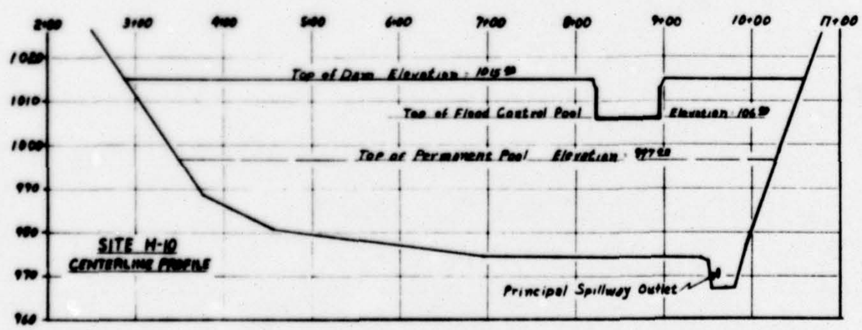

Top of Dam El. - 805
20'
Top of Flood Control Pool El. 796.0
Top of Permanent Pool El. - 780.0
6 Antiseep Collars @ 22'00" C.C.
Original Ground
Original Channel Bottom
R/c Pipe
Cutoff
Rock
Original Ground Line
Outlet Channel Bottom
X-SECTION AT PRINCIPAL SPILLWAY CENTER LINE
Scale in Feet

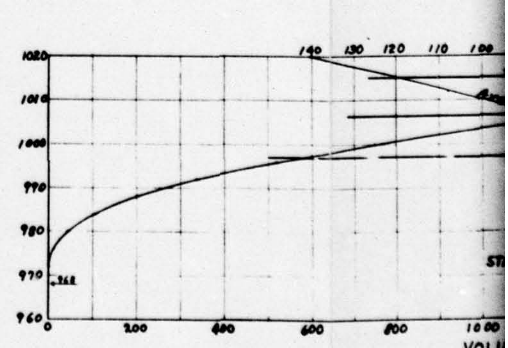

Top of Dam
Elevation 1054
Top of F.C. Pool
Top of Permanent Pool
Principal Spillway Outlet
SITE H-25
CENTERLINE PROFILE


AREA (in Acres)
Top of Dam
Top of Flood Control Pool
Top of Permanent Pool
Volume
Area
SITE H-25
STAGE-STORAGE INFORMATION
VOLUME (in Acre-Feet)

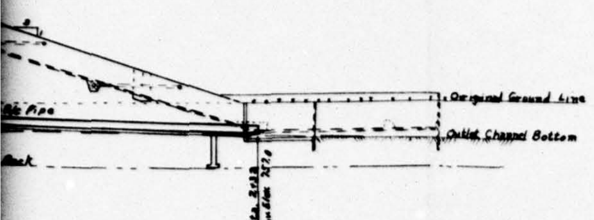

Top of Dam
Top of Flood Control Pool
Top of Permanent Pool
SITE H-4
CENTERLINE PROFILE
Principal Spillway Outlet

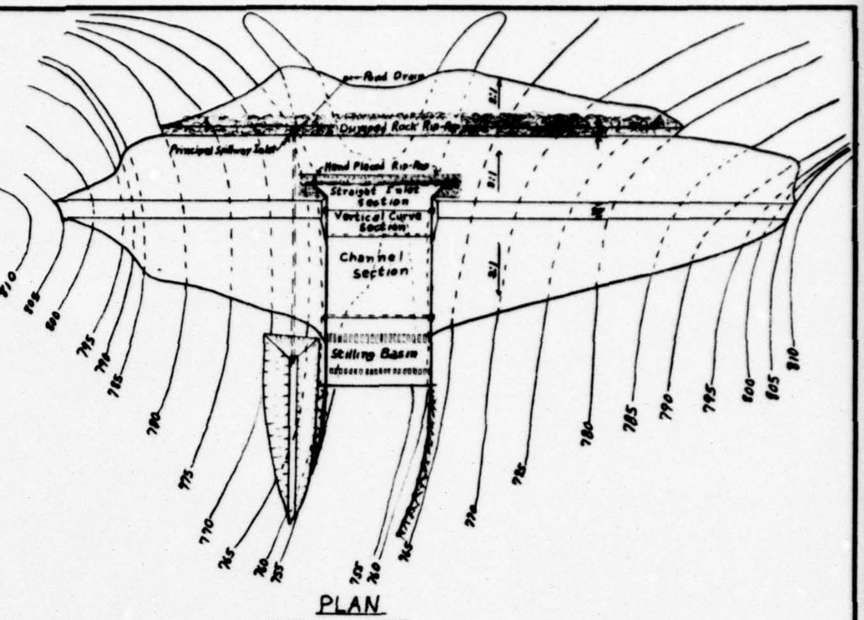

Top of Flood Control Pool
Top of Permanent Pool
Volume


Top of Dam
Top of Flood Control Pool
Top of Permanent Pool
SITE H-10
CENTERLINE PROFILE
Principal Spillway Outlet

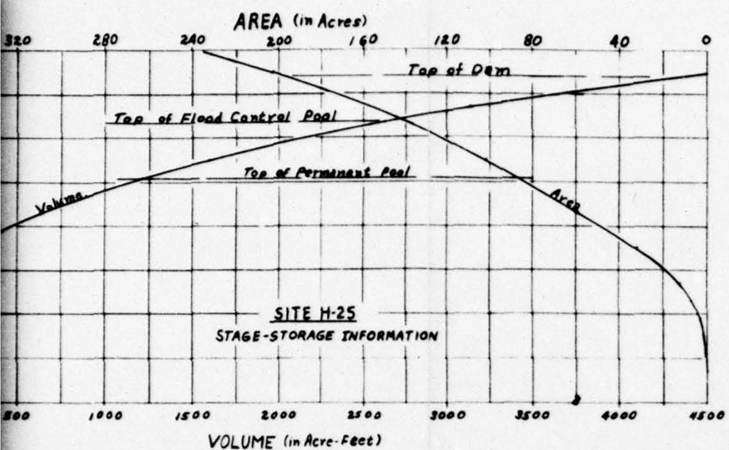


1

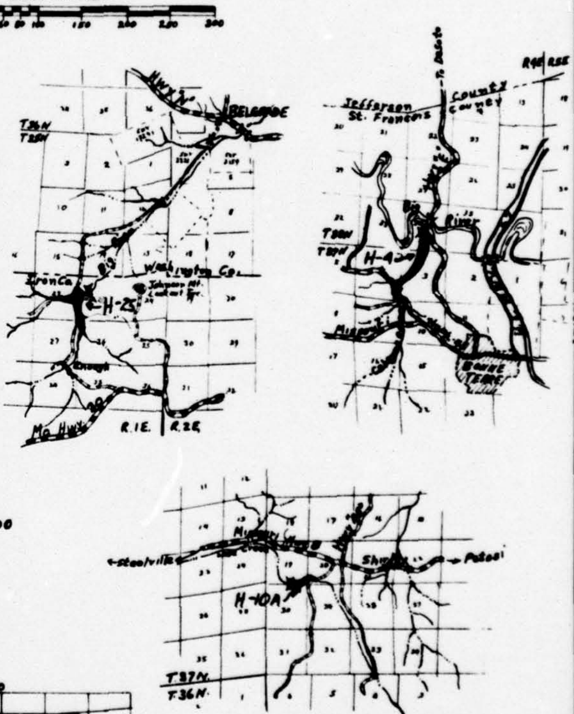




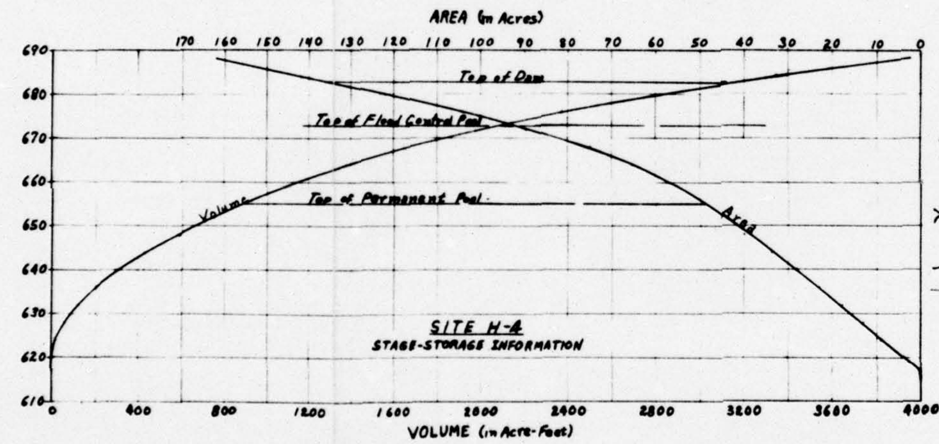
PLAN
TYPICAL LAYOUT



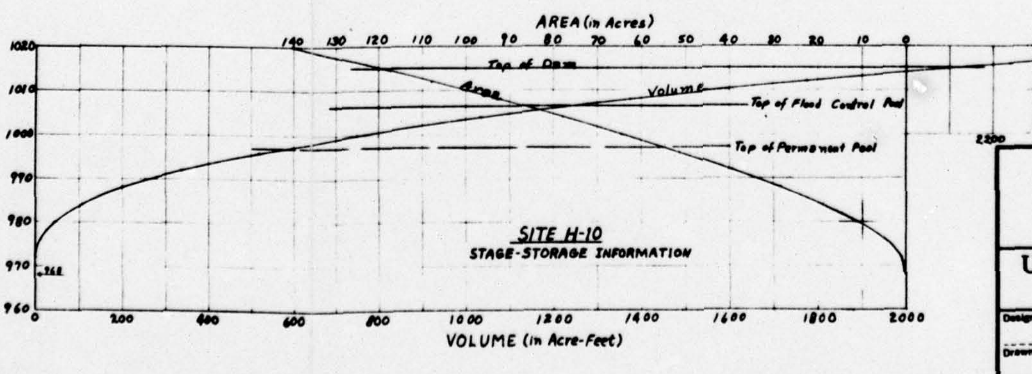
SITE H-25
STAGE-STORAGE INFORMATION



SITE LOCATION MAPS



SITE H-4
STAGE-STORAGE INFORMATION

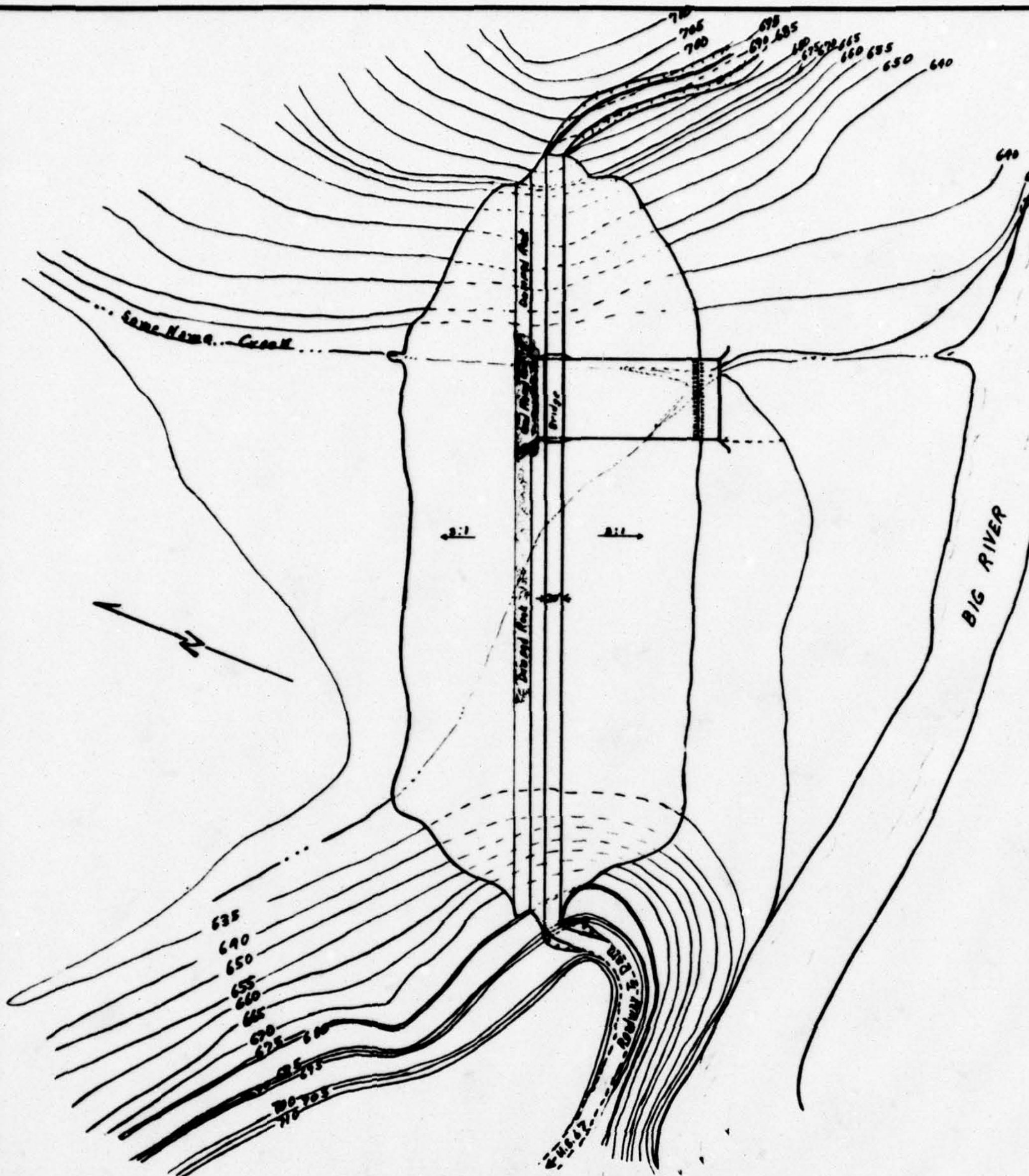


SITE H-10
STAGE-STORAGE INFORMATION

MERAMEC BASIN SURVEY
HEADWATER "H" RESERVOIRS
CHUTE SPILLWAY TYPE
(STRUCTURES H-4, H-10A and H-25)

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

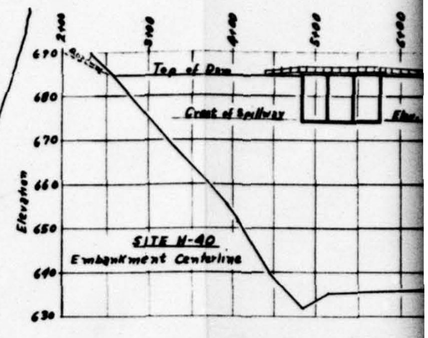
Designed KGA.	Date 4-63	Approved by	
Drawn KGA.	5-63	Title	
Traced		Title	
Checked		Sheet No. 1 of 1	Drawing No.

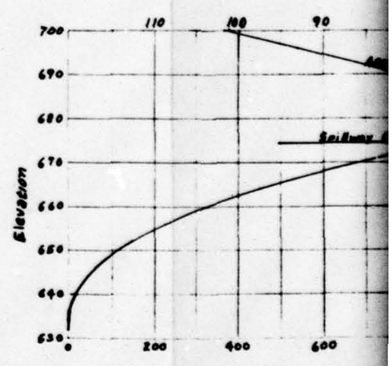


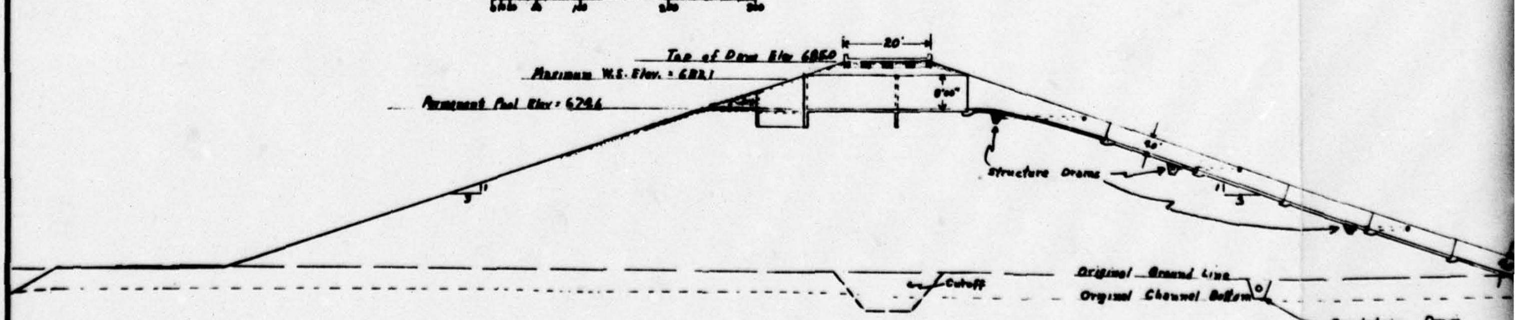
PLAN

TYPICAL SINGLE SPILLWAY STRUCTURE (OVERFLOW TYPE)

Scale in feet

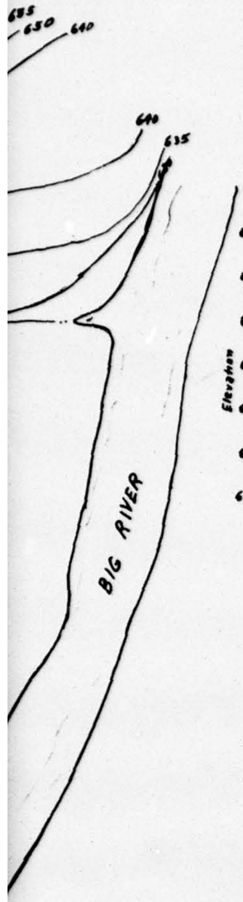


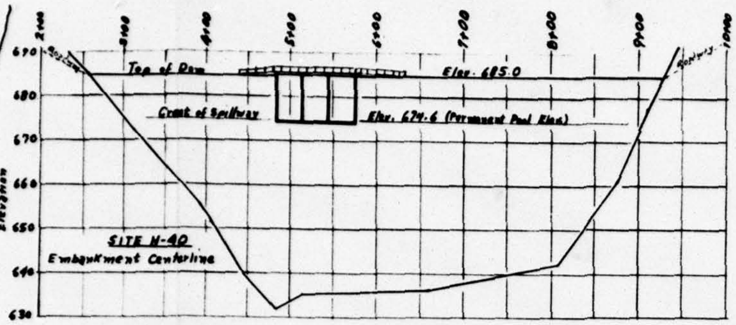


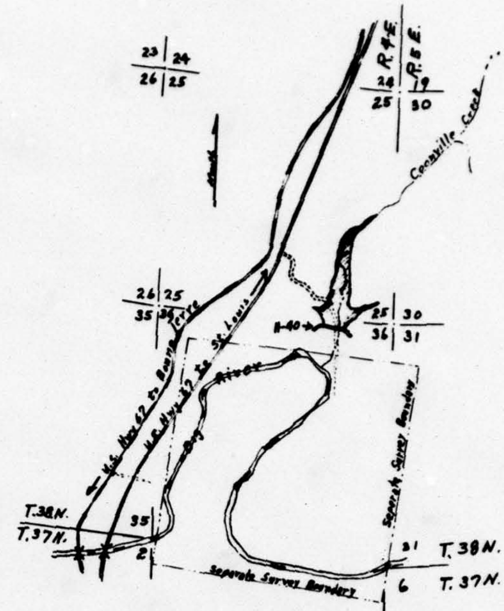


SECTION ALONG CENTER LINE OF TYPICAL CHUTE SPILLWAY

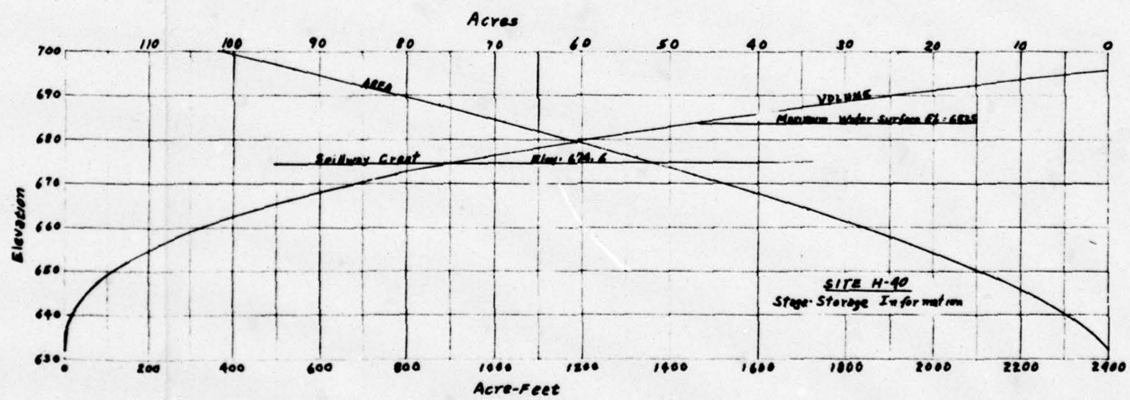
1



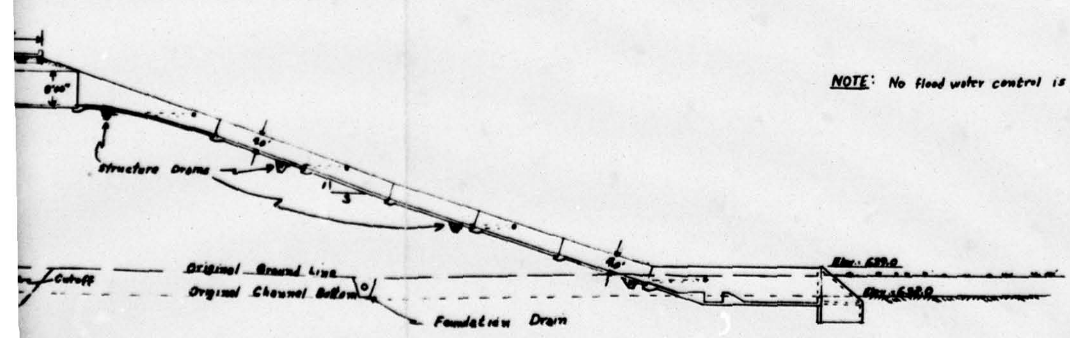




LOCATION MAP



NOTE: No flood water control is provided in current plans for Structure H-40.



ER LINE OF
C SPILLWAY

MERAMEC BASIN SURVEY
HEADWATER "H" RESERVOIRS
CONSTANT POOL TYPE
(STRUCTURE H-40)

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed KGA	Date 4-63	Approved by
Drawn KGB	5-63	Title
Traced		Title
Checked		Sheet No. 1 of 1 / Drawing No.

2

COMPREHENSIVE REPORT

MERAMEC RIVER BASIN,
MISSOURI

APPENDIX H

PLAN OF PARTICIPATION BY U. S. DEPARTMENT OF AGRICULTURE

PLAN OF WORK FOR PARTICIPATION

by the

UNITED STATES DEPARTMENT OF AGRICULTURE

IN A SURVEY AND INVESTIGATION
OF THE MERAMEC RIVER BASIN, MISSOURI

I. INTRODUCTION

The Meramec Basin, including the Meramec, Bourbeuse, and Big River Watersheds, embraces 3,980 square miles in all or part of 15 counties immediately southwest of St. Louis, Missouri.

The Basin is primarily rural, about one-half the 200,000 population being located in suburban areas near St. Louis. This area is characterized by predominantly forested headwaters, steep slopes and narrow valleys, with broadening floodplains downstream where agricultural and other uses are found in increased amounts.

Many previous studies of the Meramec River Basin have been made by several agencies since 1930. The Department of Agriculture has participated in a number of these studies since 1943. More recently, the U. S. Corps of Engineers has been authorized by Congressional resolution dated April 1960, to undertake a new comprehensive study of the Basin, which will result in the "Formulation of a plan to provide the best use or combination of uses of water and related land measures to meet all foreseeable short and long-term needs and thus insure maximum benefits to the Meramec Basin and to the economy of the Nation."

A request for participation of the Department of Agriculture in a coordinated survey effort in the Basin was made by the St. Louis District Office of the U. S. Corps of Engineers to the Administrator of the Soil Conservation Service under date of September 25, 1961. The U. S. Corps of Engineers also has requested the Department of Agriculture to provide certain specific information, which will be included in the survey.

Participation in a cooperative comprehensive river basin survey by the Department will be under authority of Section 6 of Public Law 566 and in accordance with the Memorandum of Understanding dated February 2, 1956, between the Administrators of SCS, ERS, and the Chief of FS. The principal participants within the Department of Agriculture will be the Soil Conservation Service, the Forest Service, and the Economic Research Service. Solutions to potential problems will be sought under existing authorities of the Department and under additional authorizations to the Department.

Existing information from the reports of previous studies, as well as available information from various Federal, State, and private sources, will be used to the extent it is suitable for the purpose. This plan of work assumes that proper mechanisms will be established to facilitate coordination of the Department's efforts with those of other Federal and State agencies.

It is contemplated that the survey will be completed and necessary reports be in final draft by late fiscal year 1965. Interim reports may be issued as required to effect proper inter-agency coordination during the course of the survey.

II. OBJECTIVES

The purpose of the Department of Agriculture's participation in the survey is to contribute to a comprehensive plan for the coordinated and orderly development, management, and use of the water and related land resources of the Meramec River Basin. Such a plan would provide for the highest level of long-term benefits to the people of the basin, adjacent communities and the nation.

The plan will encompass the following:

A. Identification and design of an inter-related system of structural measures for water control and water resource development and a pattern of related land use and treatment whereby long-range project needs are effectively satisfied.

B. Identification of those elements of the overall water management and control system and land use required to satisfy immediate needs.

C. Identification of those elements of the plan which should be carried out by the USDA.

III. PRINCIPAL FEATURES OF USDA STUDY

A. Inventory and classify land resources of the basin in terms of present and potential use, physical characteristics, condition, and management level.

B. Analysis of current and long range water management needs with regard to erosion control and sediment reduction, flood prevention, water supply, water quality control, fish and wildlife, and outdoor recreation.

C. Inventory of the use of natural resources by agricultural and forest enterprises and related industries and their contribution to the present and prospective economic activity and employment in the river basin.

D. Appraisal of the relationship of agricultural water problems and needs to economic development.

E. Appraisal and projection of demand for use of land and water for recreational purposes.

F. Appraisal of land and water resources available for potential recreational use.

G. In cooperation with other concerned agencies consider alternate methods of water and related land resource development and participate in the formulation of a plan of development for the basin.

H. Consideration of institutional problems and requirements for effective implementation and management.

IV. SCOPE AND RESPONSIBILITIES OF USDA AGENCIES

The survey work of the U. S. Department of Agriculture in this basin will be coordinated by a USDA Field Advisory Committee composed of Howard C. Jackson, State Conservationist, Chairman, Soil Conservation Service; A. C. Richey, Chief of Cooperative Watershed Management Branch, Region 9, U. S. Forest Service; and Nathan G. Mallett, Economic Research Service.

The Field Advisory Committee will be responsible for field coordination of the Department survey activities and procedures, arranging for field review of recommendations and reports, arranging for necessary consultations, overall relationships with the U. S. Corps of Engineers, and other interested state and Federal agencies, and arranging for overall schedules of work. Each member of the Field Advisory Committee will inform his responsible supervisor about progress and effort necessary for timely performance.

The responsibilities of each of the cooperating agencies under this plan of work are as follows:

SOIL CONSERVATION SERVICE

The Soil Conservation Service will undertake and be technically responsible for the following aspects of the survey, including arrangements for necessary technical consultation and assistance from staff members of Forest Service and Economic Research Service and with appropriate Federal and State agencies.

1. Inventory and classify land conditions, soils, erosion, and land use by land resource areas within the Basin.

2. Recommend land use adjustments and treatment to assure maximum utilization of the land resource within the capability of the lands. This will include consideration of potential recreational lands including income producing recreational use of farm lands.

3. Appraise and analyze water management needs in the Basin.

   a. Delineate sub-watershed areas into appropriate hydrologic units for purposes of the study.

   b. Identify floodwater and sedimentation problems in the subwatersheds.

   c. Appraise agricultural water management needs including irrigation and drainage.

   d. In cooperation with other agencies appraise non-agricultural water management needs in the sub-watershed areas, including municipal and industrial water supply, water quality control, recreation and fish and wildlife enhancement.

4. Determine water management needs outside of the sub-watershed which may be served by project-type water resource developments within the sub-watersheds.

5. Appraise the physical potentials and development costs of using rural water and related land resources for recreational purposes.

6. Investigate potentials for water storage developments within the sub-watersheds which will provide for needs both within and outside the sub-watersheds.

7. Participate in preparation of recommendations for water resource development within the sub-watersheds which takes account of the physical and economic relations in and outside the sub-watersheds and is coordinated with other proposed developments in the Basin plan.

8. Consider institutional problems and requirements as related to agricultural land resources for effective implementation and management.

9. Prepare a report covering USDA survey.

FOREST SERVICE

The Forest Service will undertake and be technically responsible for the following aspects of the survey, including arrangements for necessary technical consultation and assistance from staff members of SCS and ERS, and with appropriate Federal and State agencies.

1. Inventory, classification and correlation of forest resources of the Basin in terms of present and potential use, physical characteristics, condition and management levels by land resource areas, including:

    a. Conduct additional field surveys as indicated for expansion of existing or lacking necessary data.

    b. Preparation of material on National Forest Multiple Use Management as it relates to the overall USDA Basin Study.

2. Analysis of Forest Resources as related to current and long-range Water Management Needs with regard to erosion control, flood prevention, water supply, water quality, and recreation.

    a. Determination and analysis of hydrologic and related forested watershed management needs in sub-watersheds as required, including determination of hydrologic indices to be used in runoff determinations.

    b. Determination of overall forestry programs and needs as part of land treatment recommendations.

3. Inventory and analysis of the use of natural resources by forest based enterprises and related industries and their contribution to the present and prospective economic activity and employment in the basin.

4. Appraisal of the relationship of forest resources to agricultural water problems and needs. Correlate with SCS and ERS in the appraisal of the related economic development.

5. Appraisal of physical potentials and development costs of using forest land resources for recreational purposes.

6. Participation in correlation of forestry phases in development of the basin plan.

7. Consideration of institutional problems and requirements as related to the forest resources for effective implementation and management.

8. It will assure that there is correlation between this survey and the National Forest Impact Survey Report submitted by the Forest Service to the District Engineer, Corps of Engineers, early in 1963.

ECONOMIC RESEARCH SERVICE

The Economic Research Service will undertake and be technically responsible for the following aspects of the survey, including arrangements for necessary technical consultation and assistance from staff members of SCS and FS, and with appropriate Federal and State agencies.

1. Compilation and analysis of secondary statistical materials related to the agricultural economy of the basin, use of land and water resources by the agricultural industry, the resulting output of agricultural products, and levels of employment in agricultural and related economic activities.

2. A reconnaissance type appraisal of emerging improvements in agricultural production technology, growth of agricultural markets, inter-regional competition, and their likely composite consequences for the agricultural economy of the basin and its needs for natural resources.

3. Review of other studies and supplemental efforts as needed to appraise future needs for land and water for non-agricultural and non-recreational purposes.

4. An economic appraisal of agricultural water problems their adverse impact on the economy of the area, and an appraisal of economic benefits that might be derived from their alleviation.

5. Adaptation of available projections of the demand and unit use value of those types of outdoor recreation opportunities adaptable to rural type development in various areas of the basin, based on relative access to population centers and transport costs and other factors.

6. Appraise the economic potentials of rural water and related land resources for recreational use (considering, among other factors, the significance of accessibility with respect to population centers, availability of unemployed human resources, and alternative non-recreational use of the natural resources.)

7. To the extent permitted by available appropriate methods and required data, evaluate benefits and economic consequences of alternative plans and schedules of development on (a) satisfaction of demands for outdoor recreation, (b) employment and income opportunities (c) levels and efficiency of crop and pasture production, (d) levels and efficiency of timber production, and on (e) alleviation of damages from flooding and drought (to the extent feasible, the evaluations would be based on materials developed and provided by SCS, FS, and other agencies participating in the survey.)

8. Consider the possibility if time and resources permit, of a study of alternative patterns and sizes of water resource development (widely dispersed developments versus clusters of development for recreational purposes from the standpoint of efficient organization and management.)

Field Advisory Committee

/s/ Howard C. Jackson, Chairman
Soil Conservation Service

/s/ A. C. Richey
Forest Service

/s/ Nathan G. Mallett
Economic Research Service

March 27, 1963

Approval of Washington Advisory Committee in letter from D. A. Williams, Administrator, SCS, dated April 30, 1963, signed by Gladwin E. Young, Acting.

COMPREHENSIVE REPORT

MERAMEC RIVER BASIN,
MISSOURI

APPENDIX I

REPORT ON FOREST RESOURCES POTENTIAL

U. S. DEPARTMENT OF AGRICULTURE

FOREST SERVICE

MERAMEC RIVER BASIN, MISSOURI

REPORT ON FOREST RESOURCE POTENTIAL

(Preliminary Report)

Revised January, 1964

Submitted: Karl A. Davidson

Approved: A. L. Richey

Date: February 4, 1964

Residents and visitors in the Meramec Basin are blessed with an abundance of rolling and mountainous wooded landscape. Renewed each spring, this haven for wildlife also provides summer shade and scenery for recreationists and a colorful setting as the hunter takes to the field in autumn.

Among the benefits provided by the $1\frac{1}{2}$ million acres of forest are many that cannot be evaluated in monetary terms. Roads and trails provide hunting and fishing access, but the value of the pleasure afforded excapes detection.

These woodlands, besides providing the readily apparent aesthetic and economic values, have other demands and contributions. The protection of woodlands from fire, poor logging practices, and damage from livestock can result in improved growth rates, ground cover for soil protection, reduction of flood losses and improved wildlife cover and general woodland appearance to recreationists.

Nationally, forests cover 34 percent of the land and provide forestry connected employment for 5.4 percent of the people. The Meramec Basin is nearly 60 percent forested, but forest connected employment is reported at about one percent. Improving this percentage means greater utilization of timber resources and development of industries. There are now 52 wood-using industries which provide a 17 million dollar contribution to the gross economy of the Region.

In analyzing the future of this Basin resource, it is necessary to have some concept of the present and future inventory and trend for the developments which depend upon forest resources.

RESOURCES

Present

The timber resource available from the 1,479,580 acres of forest land is listed in Appendix B. The volume of growing stock on these acres totals nearly seven million cords. Sawtimber volumes have increased in the past ten years by ten percent. Poletimber has increased at even faster rates and in ten years has increased its proportion of the total volume by seven percent. Outlets for products have been to sawlog markets leaving the harvestable poletimber relatively unused. This accounts for the excessive buildup of poletimber inventory.

Slightly over two percent of the commercial forest lands has been changed to other uses in the past ten years. Most of this has gone to agriculture. Other uses amount to less than fifteen percent of the total conversion.

A look at Appendix Table B, Timber Resources of the Basin, reveals that most of the growing stock is hardwoods. Softwoods and soft hardwoods make up about thirteen percent of this volume. This is based upon preliminary information developed by the Missouri Forest Survey in 1958-1959, and is subject to revision.

The timber resources shown indicate, for the area within the Basin, the condition of the woodlands covering the landscape. This growing stock averages slightly less than five cords per acre and includes a substantial amount of cull and low value material.

Future

The timber resources for the year 2060 shown in Appendix B are based upon 250,000 acres less commercial forest land, greater volumes of pine and improved quality of trees. This growing stock is within the Basin only. It does not extend over the entire area covered by the working circles.

These increases represent a projection of three percent per year based upon growth in the last ten years, but reducing as optimum stocking is approached.

Softwood volume will increase at a much faster rate than the volumes for other species. This reflects increased area of pine or oak-pine types which results from increased protection and management. This is desirable since softwoods can be used in lumber markets with obvious success and are needed in many pulping operations. Improvement in watershed conditions also results from this type conversion and management.

In projecting the resource data for the woodland areas to a period 100 years in the future, certain basic assumptions must be made:

1. Population increases will continue to be rapid and coupled with high standards of living.
2. Technological advances in processing of forest products will continue at least equal to present rates of improvement and discovery.
3. Markets for wood fiber products will increase in this area as a result of both No. 1 and No. 2 above.
4. Loss of commercial forest land to other primary uses will continue at about the current rate to account for recreation, agriculture, industrial and urban needs.
5. Optimum levels of forest management and protection are provided on all forest lands in the Basin.
6. Even under this level of management, not all forest lands would achieve full development of the growing stock by the end of the projection period.
7. Changes in the relationship of sawtimber volume to poletimber volume to include more sawtimber in stands.
8. Conversion, due to improved management, of some oak-pine types to pine and some oak types to oak-pine resulting in greater proportional increases in pine volume than in other species groups.

The projection of future desirable cut shows the total amount of material that could be removed under good management practices within each working circle (Appendix C).*

*The working circle is that area within fifty miles of the center or point of industry concentration.

Consider the growing stock as capital and growth as interest received as a result of the investment of the capital. If, as we have projected, the growing stock doubles (less than five cords per acre to ten cords per acre) and if we assume the growth rate remains the same, then we could remove in the future at least double the amount we can remove now. This is an over-simplification of the projection, but illustrates the theory behind the future desirable cut.

Current desirable cut is 63 percent of the current growth to allow for building up the growing stock. The future desirable cut is 90 percent of growth.

A further analysis might change these figures to a small degree, but the relative expansion of the resources available indicates that large production operations are possible insofar as the timber resource is concerned. Quality projections are, however, not as favorable as these on quantity.

Appendix D shows the annual wood requirements of each of the mill type examples listed. A comparison of these needs to the resources in each working circle (Appendix C) shows the size of an operation that could be established.

Many uses could be made of this resource. We have assumed so far that sawlog production may double. Charcoal production may well double also. Fuelwood, now held high by use for home heating, will decline until its primary market is for fireplace use. Home use of fuelwood could conceivably increase beyond that point in proportion to population growth.

MARKETS

Present

Existing products from timber harvested in the Meramec include sawlogs, fuelwood, charcoal, posts and poles and mine timbers. A recent intensive sampling of industries (September, 1963) found no production for cooperage markets active in the Basin.

Most sawmills produce rough lumber at a rate of less than one million board feet per year. Fifty-seven percent of these are part time operations. Sawmills provide two-thirds the total number of individual markets for timber products and handle the largest volume of harvested growing stock.

Fuelwood use in Missouri has declined in the past ten years, but total timber volume consumed for this use is greater than for any other use. It exceeds the total volume in sawlog production through utilization of tops and limbs not included in growing stock volume figures. Use of growing stock for fuelwood is about one-third less than use of growing stock for sawtimber.

Pulpwood use at present is very meager with only two mills now located in the state, neither in the area of this Basin. Posts and poles are nominal markets and other uses, including charcoal wood, mine lagging, lath and shingle bolts, etc., account for a few percentage points of the total.

Future

Projections of national demand for sawlog products based on no per capita change in consumption indicate a 129 percent increase by the year 2000. Much of this may be provided for by imports which reduce the demand upon native timber to a doubling of current consumption.

If this trend is reflected in the hardwood sawtimber market in Missouri, we might well expect a 100 percent increase in local mill output by the year 2060.

Current production in the Basin is about 27 million board feet annually. If this were to go to 80 million board feet by 2060, we can expect substantial increases in current mill production and numbers of mills.

In the immediate future, it is expected that the number of mills will remain static, with new mills replacing mills that go out of production. Increased demands for lumber and other sawn products normally reflect an increase in the number of mills brought into production. An increase in growing stock and quality of timber will provide the resource leaving increased production dependent upon improved markets.

Fuelwood, as the next largest current use of growing stock, may well be expected to decrease in total consumption as standards of living improve and as timber stands improve in quality and value. The national average use of fuelwood is currently less than half the consumption in Missouri. A reduction in this use will have little effect upon monetary returns to landowners and resulting employment. Increases in woods work directed toward other markets should far overshadow the losses in employment based on a fuelwood market.

Many studies have been conducted on the feasibility of pulpwood market development in Missouri. This is understandable considering the relative abundance of cordwood available but not used. Hard hardwoods are the major part of this resource and figure prominently in the analysis of these possibilities.

All studies indicate a healthy trend toward expansion in national pulpwood markets. The largest increases are expected in manufacture of products for changing uses such as food containers and other markets directly affected by expanding populations.

At the present time, industrial capacity nationally is in excess of pulp production indicating construction of new plants will be aimed to meet rapidly expanding markets. Hardwood pulping processes have made it possible

for these species to be used for these new markets. This trend of changing markets and increase in use of hardwood pulp for many products could result in greater use of the Missouri hardwoods in the pulping industry.

Hardwood pulps are finding their way into increasing use in other markets such as newsprint. Higher proportions of hardwoods are desirable in certain paper products. Hardwood pulps can yield hard, dense sheets or soft, bulky, abosrbent products. Since density of insulating boards and hardboards is dependent upon process more than on species, hardwoods can be as suitable as softwoods for this product.

From a technical standpoint it appears that hardwood pulp production - reducing imports and utilizing new markets - has a real and rapidly expanding future.

Since the Basin has the resources available now and could apparently double its resources in the next 100 years, it seems logical to assume that resources will not be a limiting factor for establishment of pulping industries in this area.

Since at present there are no pulping operations in the Basin, any increase in the pulp industry within or adjacent to the Basin will have a significant impact.

If located on a site outside the Basin, these contributions would be in returns to landowners for purchase of wood, some limited employment increases, and possible increases in employment in services resulting from the mill. An increased need for forestry services would exist to provide the management services necessary for supplying the resource to the mill. This same service would be required if mills locate within the Basin.

Additional impacts will result if a mill were to locate in the study area.

Increases would be in tax base, employment, use of water, pollution control, drain on the forest resources and services connected with operation of the industry. Appendix D shows the relative size of these impacts.

Another use of the wood resources is in charcoal production for domestic use. Missouri currently produces more charcoal than any other of the Central States. The Central States provide over ten percent of the total national production. Missouri's share of national production is more than seven percent. About half of Missouri's kilns are within reach of materials within the Basin. The center of the industry in Missouri is now in Osage County adjacent to the northwest corner of the Basin. It is reasonable to assume that expansion of this industry will have an effect upon use of the resources in the Basin.

Many other possible markets would also be available as outlets for Basin timber. These would include natural and pressure treated posts, poles, pilings and timbers; chip and sawdust waste products; and markets not now more than a researcher's idea.

All of these markets will have to rely on the resources available from management of the woodlands. The future of forest industries is based not only on future of markets, but also on future resources.

IMPACTS AND CONTRIBUTIONS

Demands

The figures in Appendix C indicate the preliminary estimate of "Desirable Cut." This is based upon use of about 63 percent of the growth with the remaining 37 percent allowing for improvement of the growing stock. The "Estimated Drain" is deducted from this allowable cut and includes all products being removed and the additional sawlog material of higher quality and value which should be used for lumber or other sawtimber products. The available resource is that material now available for supplying a pulpwood market and not now being utilized for any one of a number of reasons.

These cut estimates (Appendix C) are based upon total resources available, regardless of Basin boundary, in the working circles indicated. Each of these assumes that material from adjacent working circles would be utilized within that circle.

Good logging practices protect streamflow and reduce silt loads of streams. Use of the timber resource provides employment for woods workers, truckers, mill operators and others providing services for these people. Sawmills, charcoal kilns and other industries located in the Basin create little impact upon water availability and stream pollution. These are small, well distributed establishments creating no concentrated impact.

Employment in the charcoal industry in the production phase is not very great. Impacts of this industry on employment may be only a small part of the total forest-based employment.

Water requirements and pollutants are negligible when compared to pulp or other water using mineral industries.

Many outlets for timber not now found in the Basin might develop. The most pronounced of these would be a pulp market. Any one of the listed types (Appendix D) might appear and processes not now recognized can be expected to develop and may locate here.

Appendix E indicates some of the contributions estimated, under current conditions, to be attributed to industrial development. The most important of these affecting the water resources are the pulp industries.

Immediately upon looking at the water requirements and pollution levels indicated in Appendix D, it might be assumed that we must know when and precisely where such operations will be installed.

A large, well-known paper industry has located on the heavily used Sacramento River in central California and has found it possible to economically use water within the required limits and treat the effluent to reduce the damaging factors to well below the necessary levels. Another industry in Georgia has gone a step farther and raises fish in their last effluent pond and releases these along with the water returning to the stream. Other examples are also coming to our attention.

This recent experience in establishment of high water using - high pollutant producing pulping installations at new locations indicates that new technology reduces both of these problems to any level considered acceptable by water resources or water pollution agencies. This trend is recognized by industry and these costs are being considered a part of manufacturing expense.

A 1960 Report by the Public Health Service and Missouri Water Pollution Board has ruled out the Meramec Basin as a possible site for the pulp industry because of these water requirements and pollution levels. Any standards set by the water controlling agencies, if they can be reasonably met, do not necessarily mean a plant will not locate. It is our feeling that pulp operations will eventually consider cost of effluent treatment a part of normal production cost.

Recent independent studies indicate just such an operation might be feasible in the upper reaches of the Big River. We cannot assume that the same would not apply to other areas. If Missouri timber development keeps pace with the national trends, we can expect this development. The impacts will not be on the water resource.

Benefits

Benefits will be in employment and increased dollars in the local economy. Estimates of the degree of these are dependent upon the type of operation considered. Attempts. to estimate the types of pulping operations, number of new sawmills and charcoal plants and persons employed in the woods work, and other related services have been limited by insufficient data. If numbers of persons employed in these industries remain constant relative to production, then doubling sawmill and charcoal production should double employment.

New operations will provide new jobs for anywhere from five men in a small sawmill operation to 500 men as the result of a large pulp operation.

SUMMARY AND CONCLUSIONS

Over half of the Meramec Basin is in forested land use. This has a potential for timber production, recreation, erosion control, and watershed protection, employment opportunities and aesthetic values.

Although improving at a noticeable rate, help is needed for improving the contributions available from the woodlands. Management, protection, and new markets for the large volume of hardwoods can double the contribution to the economy in terms of jobs and income.

Impacts on water resources will not be appreciable since new industires can be expected to reuse water and treat effluents in order to keep within the limits of the water resource requirement. Most forest industries are small and scattered and do not create impacts on water availability and pollution.

Contributions to streamflow from forest management will be most noticeable in terms of silt load reduction. Other benefits will be in terms of employment and dollars in the overall economy.

Wildlife, recreation, aesthetic and many intangible benefits are reoognized but difficult to evaluate. All will benefit from a comprehensive forest management and protection program.

APPENDIX

A. Forest Acreage of the Basin

	Percent	Acres
Federal Ownership	13	191,174
State Ownership	2	36,508
Private Ownership	85	1,251,898
	100	1,479,580*

*Reduced by 250,000 acres in 2060 (Reduction of Commercial Forest Land)

B. Timber Resources of the Basin (Preliminary Estimate - 1959)

	Poletimber Trees Thousand Cords	Sawtimber Trees MBM	Total Thousand Cords
Softwoods	591	92	776
Hard Hardwoods	5,834	978	7,790
Soft Hardwoods	239	50	338
Total	6,664	1,120	8,904
Percent	75%	25%	100%

Timber Resources of the Basin (2060)

	Poletimber Thousand Cords	Sawtimber MBM	Total Thousand Cords
Softwoods	800	430	1,660
Hard Hardwoods	6,330	1,950	10,230
Soft Hardwoods	380	175	630
Total	7,510	2,555	12,520
Percent	60%	40%	100%

C. Desirable Annual Cut (Thousand Cords)

Working Circle	Species Group	Total Desirable Cut: 1959	Total Desirable Cut: 2060	Estimated Drain* 1959	Available Resource 1959
Sullivan-Washington	Softwoods	3	10**	2	1
	Hard Hardwoods	196	437	121	75
	Soft Hardwoods	9	28	5	4
	Circle Total	208	475	128	80
Salem-Steelville	Softwoods	8	28	3	5
	Hard Hardwoods	188	419	106	82
	Soft Hardwoods	9	28	5	4
	Circle Total	205	475	114	91
Flat River-St. Genevieve	Softwoods	12	41	5	7
	Hardwoods	242	540	180	134
(20% in Illinois)	Soft Hardwoods	11	34	7	4
	Circle Total	265	615	120	145

*Includes that material which should be utilized in the sawlog markets.

**Current Desirable Cut is 63% of Growth - Projected Cut is estimated at 90% of Growth.

D. Requirements of Operations by Type of Process

Type of Mill	Daily Mill Capacity	5-day B.O.D. of Effluent Per ton air-dry	5-day B.O.D. of Effluent Per Day	Manpower Man Hours/day*	Electric Power K.W. Hrs./Day	Wood Annual Consumption Thousand Cords	Water Thousand Gallons Per Day
	Tons air-dry	Pounds	Pounds				
Groundwood (Softwoods & Soft Hardwoods)	100	6	600	300	130,000	50	100-6900
Semi-Chemical (Mixed Hardwoods)	200	125	25,000	1,000	60,000	100	1400-2400
Bleached cold soda (mixed hardwoods)	100	90	9,000	500	25,000	50	3300-9000
Bleached sulfate (mixed Hardwoods)	300	75	22,500	1,500	75,000	250	3300-9000
Sawmill	MBM 10	0	0	80	50**	6	0-1
Charcoal Kilns	Tons 10	0	0	240	1	8	0

*Manufacture only - Estimated number employed.

**Electrically operated mill - Many mills are diesel powered and may use no electric power.

E. Contributions of Operations by Type of Process

Type of Mill	Daily Mill Capacity	Estimated Construction Investment Thousand $	Estimated Contribution* To The Economy Thousand $/yr.	Comments
Groundwood pulp	Tons air-dry 100	unknown	1,200	Possiblity of establishment - unknown.
Semi-Chemical pulp	200	15,000	2,500	Any one or a combination of these processes might be expected in the next ten years. Actual capacity will be determined by market conditions and wishes of the owners. Resources will not be a limiting factor.
Bleached cold soda pulp	100	6,000	1,200	
Bleached sulfate pulp	300	40,000	4,000	
Sawmill	MBM 10	100	150	Stable in numbers until markets increase then growth can be expected to parallel increases in population.
Charcoal Kilns	Tons 10	30	300	Will increase in proportion to markets - continued growth is expected.

*Includes returns to landowners for stumpage, employment in processing and supplying resources to mills and associated services.

COMPREHENSIVE REPORT

MERAMEC RIVER BASIN,
MISSOURI

APPENDIX J

MINERAL RESOURCES AND MINERAL INDUSTRY

MINERAL RESOURCES AND MINERAL INDUSTRY

OF THE MERAMEC RIVER BASIN, MISSOURI

PRELIMINARY REPORT

by

Division of Mineral Resources
U.S. Bureau of Mines
Region IV, Bartlesville, Oklahoma

MARCH 1963

FOREWORD

The following report presents an analysis of mineral resources and mineral industry in the Meramec River Basin, Missouri. Previous studies of the region have been conducted by private, Federal, and State agencies. Most recently, Dr. E. L. Ullman and staff made an economic evaluation of the Basin in a report for the Meramec Basin Corporation. Prior to the war, cooperative studies by several Federal and State agencies resulted in publication of a report on the Basin in 1948. Although the earlier reports contained much valuable data, conclusions reached by the Federal and State agencies were based on pre-war conditions and mainly concerned water.

As requested by the U.S. Army Corps of Engineers, the Bureau of Mines, Region IV, conducted an investigation of mineral resource involvement in the proposed Meramec Basin Project. The study was coordinated with other projects and activities of the Division of Mineral Resources. The following personnel contributed to compilation of data and preparation of the report:

R. S. Sanford, Acting Regional Director, Region IV

J. C. Arundale, Assistant Chief, Division of Mineral Resources

H. F. Robertson, Supervising Mining Engineer

W. G. Diamond, mineral specialist

T. R. Early, mineral economist

H. D. Kline, mining engineer

A. Kuklis, mining engineer

F. F. Netzeband, mining engineer

R. K. Stroup, mining engineer

NaDean Prather, draftsman

Lorraine Collier, statistical clerk

Peggy Daxon, typist

Dorothy Smith, typist

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ILLUSTRATIONS

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INTRODUCTION

This preliminary report on the mineral resources and mineral industry of the Meramec River Basin in Missouri was prepared by the staff of the Division of Mineral Resources, U.S. Bureau of Mines, Region IV, for the U.S. Army Corps of Engineers, in accordance with Authorization No. 3854, Work Order No. 341-W2. Objectives of the work were as follows:

1. Make a survey of the mineral resources and industry within the Basin.

2. Determine the effects of the proposed reservoirs on the mineral resources and industry in the area.

3. Evaluate the impact of mining on the future economy of the Basin.

4. Comment on the effect of mineral industry on water resources - both water consumption and water quality.

Data for the report were obtained by field reconnaissance, from published and unpublished material of the Missouri Division of Geological Survey & Water Resources, Federal Bureau of Mines, and technical publications as listed in the Selected Bibliography at the end of each commodity section.

Field surveys of the mineral resources and mineral industries in southeast Missouri were conducted during September and October 1962. Four mining engineers spent a total of 35 days examining active mineral properties and conferring with company personnel. Two economists contacted various State and municipal agencies for background data.

It was not possible to visit all active producers in the Basin or to make comprehensive economic evaluations of the future demand for all mineral commodities during the period of this study. Projections included in this study are not a result of detailed economic analysis of the area, commodities, and/or industries. Moreover, certain data, essential to valid economic projections of the mineral industry in the Basin and adjacent area, could not be obtained from individual companies.

The time limit imposed on this report precluded detailed field surveys of the 32 proposed reservoir sites to ascertain effects on the mineral resources. Because the location of a reservoir may be influenced by the presence or absence of minerals, it is imperative that a thorough study of potential resources in the proposed reservoir areas be completed prior to the final selection of the damsites.

Conclusions reached in this report are based on professional judgment and a critical analysis of collected published and unpublished information.

SUMMARY

In 1961, about one-third of the total value of Missouri's mineral production originated in or immediately adjacent to the Meramec Basin. During the next decade, this figure should reach 40-50 percent. Of the labor force attributed to the mineral industry of the State, over 50 percent are employed in this area. The mineral industry of the Meramec Basin, through related industries, direct payrolls, and capital

expenditures contributes significantly to the economics of the State. Of more importance, the minerals known to exist in this geographical area provide an excellent resource base for further economic and industrial development of Missouri.

Metallic and nonmetallic resources of commercial importance in the Meramec River Basin, Mo., consist of iron, lead, barite, clay, sand and gravel, and stone.

Paleozoic (hematite) and Precambrian (hematite and magnetite) iron deposits occur in the Meramec Basin and adjacent area; however, only the latter are economically important. More than 240,000 long tons of iron ore was produced in 1961 by M. A. Hanna Co., Missouri Division in St. Francois County.

The discovery of several large Precambrian iron ore deposits has been reported and mining of the Pea Ridge ore body is in the final development stages; substantial production at Pea Ridge is anticipated by yearend. It is possible that other discoveries will be placed in production within the next several years. A significant impact on the future economy of the Basin will be realized by the development and exploitation of new iron deposits in the area.

The southeast Missouri "lead belt" lies within or adjacent to the Meramec Basin and has been a major source of domestic primary lead to the national economy. Basin mine production in terms of metal value accounted for 38 percent of the domestic output in 1961. New large lead deposits have been discovered near Viburnum in Iron, Crawford, and Washington Counties, and near Oates in Iron and Dent Counties.

St. Joseph Lead Co. placed into operation two mines in the Viburnum area; production from a third shaft is scheduled in 1963. Other major mining companies should be developing their holdings within the next several years. This development could require lead milling, smelting, and refining capacity to process the new production.

As a result of mineral deposits amenable to mechanized operations, available lead smelting and refining facilities, and adequate labor, water, and transportation facilities, the Basin lead industry is expected to maintain its position as a major domestic supplier of lead and associated metals.

Barite production data indicate that mining has been continuous from 1872 to date. Missouri's total output is in excess of 8 million tons valued at more than $74 million. In 1961, shipments of barite valued over $3.1 million were recorded. The output was mined in Washington County, which is entirely within the Meramec Basin. Barite mining and milling in the county provides employment for a total of 398 workers. Of significance to the future of the industry, barite produced in the Meramec Basin area is of higher grade than that generally produced in the United States. Technological changes in mining and beneficiation are expected to supplement the present known reserves in the Basin and extend the economic life of the industry.

Refractory clays classified as diaspore, burley, flint, and plastic are mined in the Meramec River Basin and accounted for employment of approximately 329 workers in 1961. Clay mining began in 1883 and the industry expanded steadily until 1953 when peak annual

production valued at more than $4.6 million was achieved. Total recorded output for 1961 was 451,212 short tons, valued at $1.75 million. Clay produced in the Basin is shipped to processing plants in Audrain, Callaway, Gasconade, and St. Louis Counties. Deposits of high-alumina, refractory clays are being rapidly depleted; however, improved techniques in beneficiation of subgrade deposits will partly offset dwindling reserves.

Five counties (Franklin, Jefferson, Ste. Genevieve, St. Louis, and Washington) are producers of sand and gravel; silica sand is currently mined in Jefferson and St. Louis Counties. The Basin's output of sand and gravel more than doubled during the period 1942-1961; furthermore, commercial production in the region accounted for 58 percent of the State's total output in 1961. The production of silica sand increased from 96,000 tons in 1942 to 488,000 tons in 1961. Requirements of Meramec Basin sand and gravel will continue to increase in line with new construction activity. An analysis of the silica sand market indicates that demand should increase with the growth of the national economy.

In 1961, stone ranked second in value of mineral production in the Meramec Basin, contributing more than $11.6 million to the region's economy. Reserves are ample to supply present and potential industrial requirements for many years. The stone industry can be expected to grow in accordance with the national economy.

ACKNOWLEDGMENTS

Acknowledgment is made to the many authors of geological and mineral economic research bulletins from which the background for this

report was secured. Special acknowledgment is made to the Division of Geological Survey & Water Resources, of Missouri, Dr. T. R. Beveridge, Director and State Geologist, and Dr. Wm. C. Hayes, Assistant State Geologist, for their contribution of data and cooperation. Special acknowledgment, both for assistance and essential information provided, is made to personnel of active barite, iron, and lead mines, refractory companies, and other mineral producers in the Meramec Basin.

LOCATION AND GENERAL DESCRIPTION

The Meramec Basin, located in east-central Missouri, extends about 100 miles southwesterly from St. Louis into the Ozark Highlands (fig. 1). The Basin encompasses two counties completely and parts of eleven other counties (fig. 2).

Approximately one-half of the population of about 210,000 is concentrated in the part of St. Louis County situated within the Basin. The total area of the region is 3,980 square miles.

Three railroads and a network of Federal and State paved highways traverse the region and provide excellent transportation. County roads - paved or graveled - and locally maintained roads form a system of secondary highways throughout the Basin.

GENERAL GEOLOGY OF THE MERAMEC RIVER BASIN

Topography

The Meramec Basin is drained by the Meramec River and its tributaries, the Bourbeuse and Big Rivers. The rivers and streams of the

SOURCE : The Meramec Basin Research Project.

FIGURE 1.- Location map of the Meramec Basin, Missouri.

FIGURE 2.- Location of counties in the Meramec River Basin, Missouri.

Basin are generally entrenched in steep valleys and have narrow floodplains. The Meramec River originates in the southeastern part of Dent County and flows north and eastward to its confluence with the Mississippi River, approximately 10 miles south of St. Louis.

Most of the Basin is a dissected plateau with the river valleys occupying a minor part of the land area. Farming is conducted on the rich soil in the valleys and floodplains. 1/ The terrain of the Basin is gently rolling in the north and becomes progressively rougher towards the south. Elevations range from about 400 feet in the northeast section to almost 1,400 feet in the southwest corner.

1/ Ullman, E. L., R. B. Boyce, and D. J. Volk. Report of the Meramec Basin Research Project. Washington University, Vol. II, 1961

Physical Geology

The Meramec Basin, located on the northeastern flank of the Ozark Dome, is underlain by rocks ranging in age from Precambrian through Pennsylvanian. Igneous rocks of Precambrian era are exposed in the southeastern part of the Basin in the vicinity of Caledonia and Irondale. The remaining area in the region is covered by sedimentary rock of the Paleozoic era; the strata dip to the east and north. The sediments of Pennsylvanian age are chiefly shales and clays interbedded with limestone and sandstone members. The older sedimentary rocks are predominantly dolomitic. Strata of Silurian age are not identified in the Basin. Major and minor faults are present and influence the mineralization in the region.

MINERAL RESOURCES

Mineral resources of the Meramec Basin consist of metallic and nonmetallic commodities, including barite, clays, copper, cadmium, cobalt, granite, iron, lead, limestone, nickel, sand and gravel, silica sand, silver, and zinc. Commercial production of these minerals and mineral byproducts in substantial quantities dates back to the early 1800's. The value of mineral output for 1961 in the Basin was more than $48 million. Listed in order of production value, lead, limestone, sand and gravel, and barite were the major commodities.

Major mining companies are intensively exploring the Basin and adjacent areas for copper, iron, and lead. More than 2.3 million feet of exploratory drilling was done during the period 1959 through 1961 (table 1). Major discoveries were made at Blair Creek, Bourbon, Boss-Bixby, Kratz Spring, Oates-West Fork, Pea Ridge, and Viburnum. A large deposit of iron ore has been developed at Pea Ridge; production is scheduled for 1963. Two shafts are currently in use at the Viburnum lead deposit; ore is expected to be mined through a third shaft in 1963. Development and subsequent production of other major mineral discoveries is in the planning stage.

TABLE 1.- Summary of drilling activity in southeast Missouri

Year	No. of reporting companies	Footage drilled		
		Churn	Rotary	Diamond
1959	10	218,482	-	617,800
1960	11	268,819	15,871	451,295
1961	10	153,555	2,791	600,641
	Total	640,856	18,662	1,669,736

TOTAL OF ALL DRILLING - 2,329,254 feet.

Over the last ten years the Meramec Basin accounted for about 36 percent of the total value of minerals produced in Missouri. Table 2 shows the relation of the Meramec Basin to the total value of mineral output of the State. A significant share of the domestic metallic and nonmetallic mineral industry is concentrated in the counties in or adjacent to the Meramec River Basin. The area is currently a major supplier of iron ore to a growing, midwest steel industry. Lead is shipped from the Basin to nationwide markets. Consequently, from an economic point of view, the mineral industry of the Meramec Basin is of importance to the national economy. It can be assumed that as a result of the intensive exploration activity of the past few years, additional mineral deposits will be developed.

TABLE 2.- Comparison of the value of mineral production in the Meramec Basin and State of Missouri, 1952-1961

Year	Meramec Basin	Missouri	Meramec Basin as percent of total
1952	$ 56,042,083	$ 140,249,000	40.0
1953	50,453,694	128,207,000	39.4
1954	53,366,168	136,288,000	39.2
1955	60,211,426	157,588,000	38.2
1956	63,050,526	170,113,000	37.1
1957	57,563,380	159,209,000	36.2
1958	48,504,508	150,538,000	32.2
1959	51,460,002	164,025,000	31.4
1960	51,781,706	162,244,000	31.9
1961	48,208,556	151,288,000	31.9

In 1960, over 50 percent of the State's mining labor force of 7,700 was employed in the Basin. Figure 3 shows in percentage terms the part this area plays in the overall mineral industry of Missouri.

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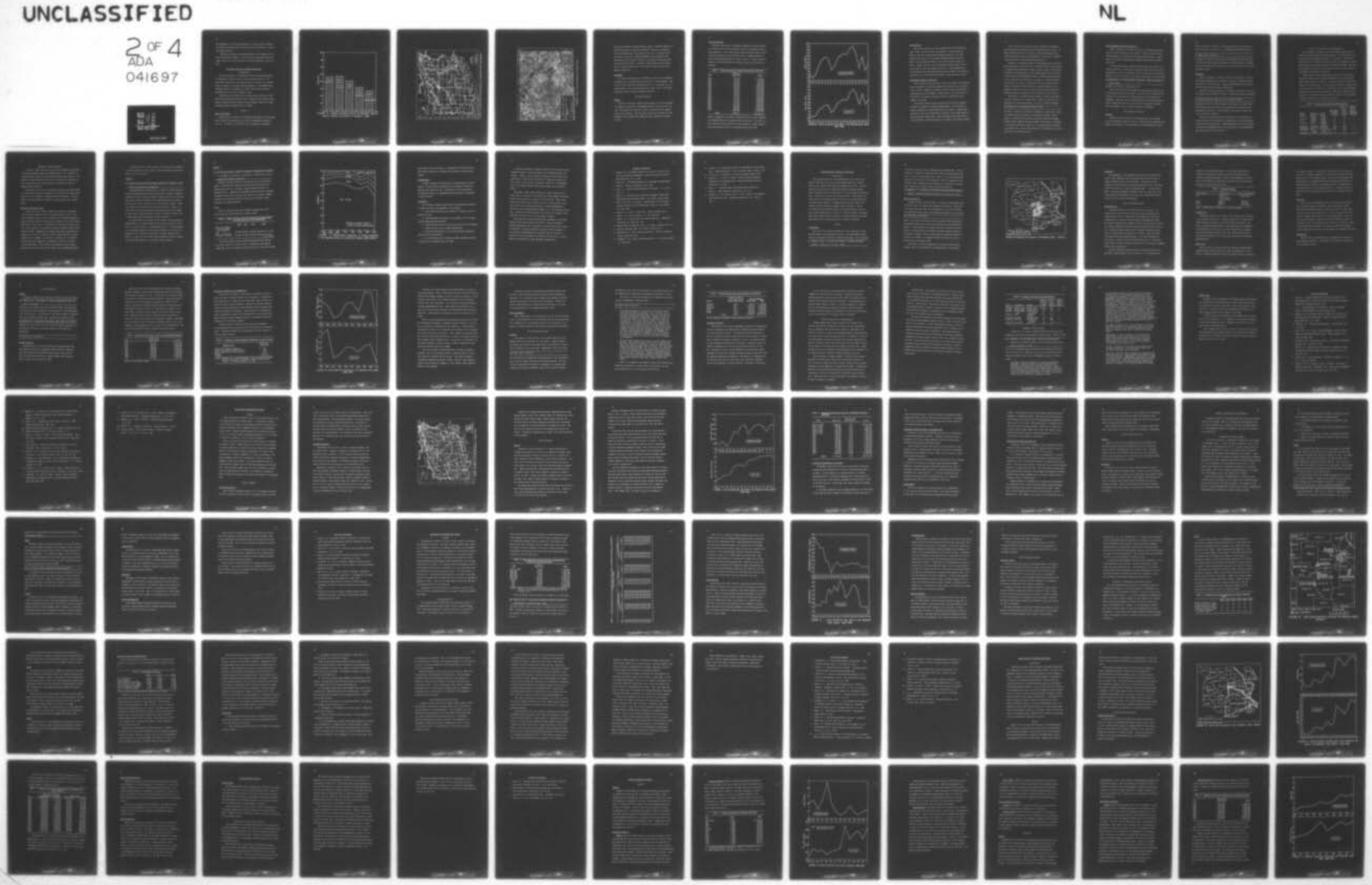

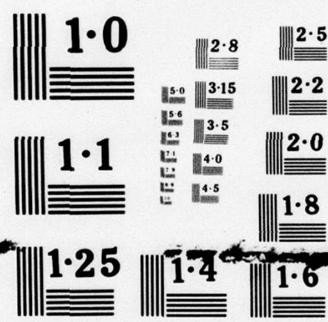
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Corresponding to the direct contribution to State and local economics are indirect economic benefits which accrue to these areas as a result of mining activities.

The mineral industry of the Meramec Basin is an integral part of State and National economics. Thus, any action that would affect the mineral industry of this area must be critically analyzed in this context.

The Barite Deposits in Meramec River Basin

Introduction

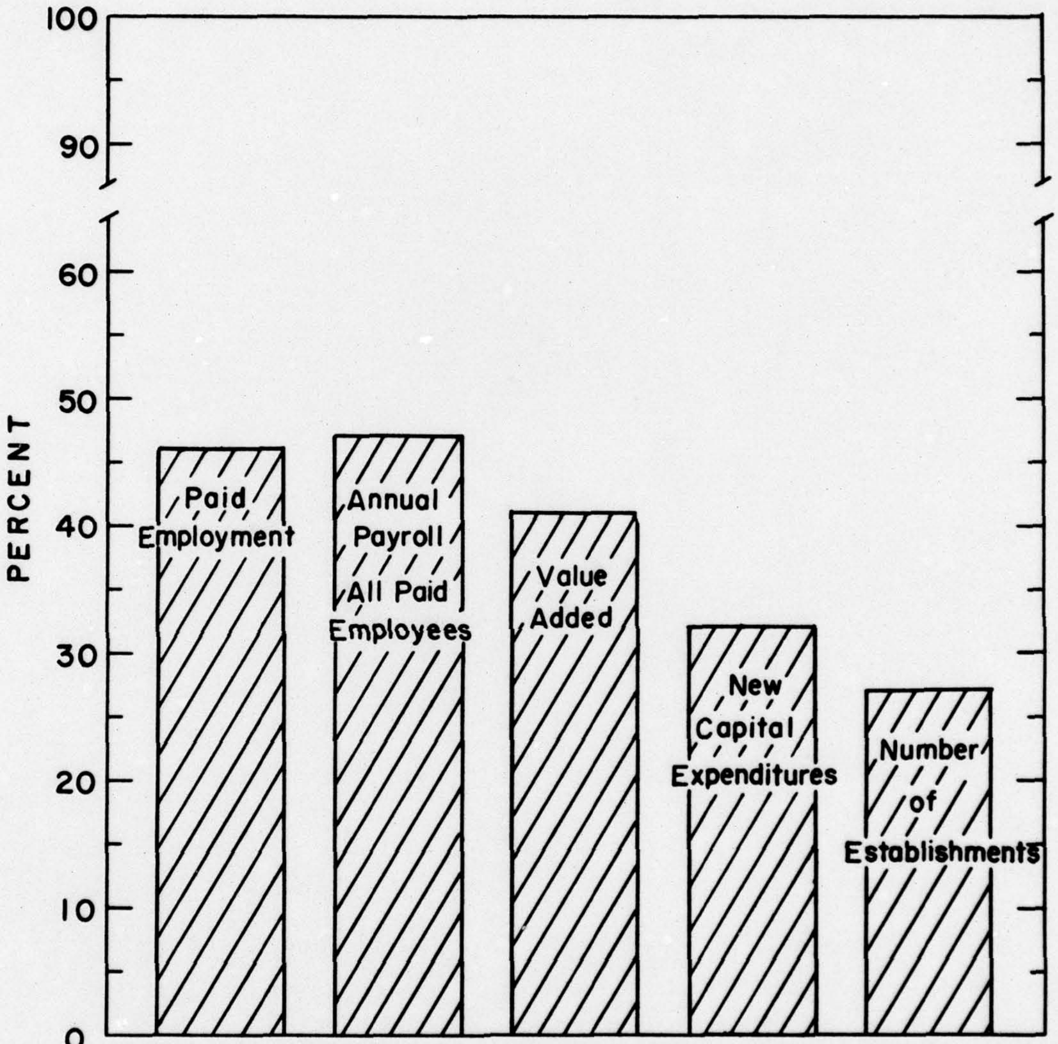
The barite deposits in the Meramec Basin are located principally in Washington, Jefferson, and St. Francois Counties (fig.4). For many years, Missouri was the leading producer of barite in the United States; almost all the output came from deposits in the Meramec Basin. Washington County is considered the center of the barite industry, producing all of the State's output in 1961.

The barite area is served by a system of State and Federal highways and the Missouri Pacific Railroad. Several barite producers have plants located along the railroad; Missouri Pacific maintains loading stations at Potosi, Mineral Point, and Cadet.

Geology

Mode of Occurrence

Barite mined in the area is irregularly distributed in red residual clays derived from weathering of the Potosi and Eminence formations (fig. 5). In Missouri, the mineral occurs throughout the geologic



SOURCE: Census of Mineral Industries, U.S. Department of Commerce, Bureau of Census.

FIGURE 3.- Salient economic factors of Meramec Basin's mineral industry as percent of Missouri, 1958.

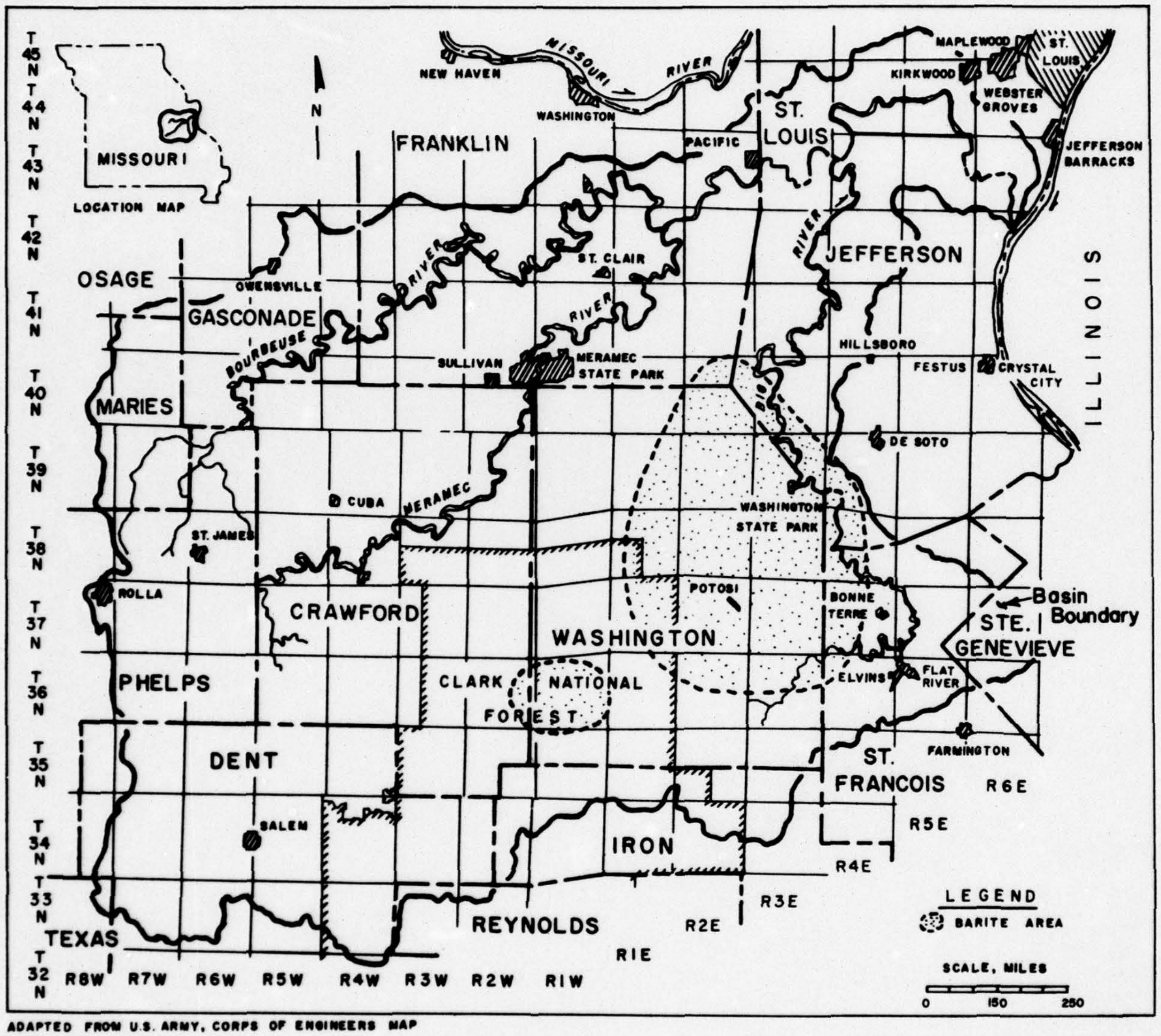
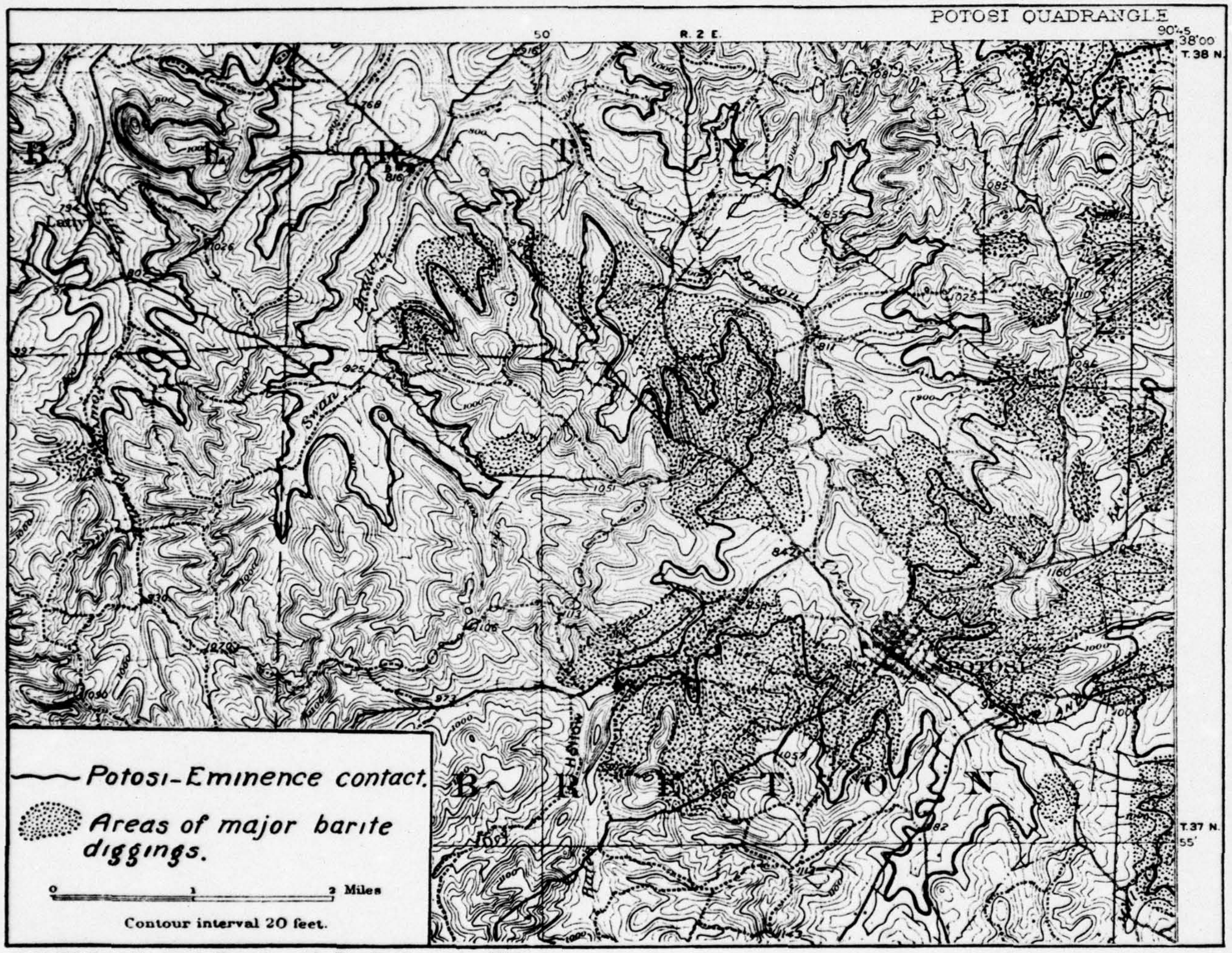


FIGURE 4.- Location map of barite resources in the Meramec River Basin, Missouri.



SOURCE: Missouri Bureau of Geology and Mines

FIGURE 5.- Map of barite producing area about Potosi.

section from Cambrian to Pennsylvanian; however, commercial deposits in the Meramec Basin are generally confined to the Potosi and Eminence strata of Cambrian age. The residual clays vary in thickness from a few inches to many feet; maximum thickness rarely exceeds 50 feet. Distribution of the barite is erratic, rich pockets alternating with practically barren ground. Generally, richer deposits have occurred near the bedrock surface and at the contact between the Potosi and Eminence formations.

Topography

The barite-producing area is underlain by the Potosi and Eminence formations and is characterized by a rolling and open topography. The soil is for the most part stony and little of it is suitable for culti-vation except in the flood plain along the larger stream. The land is wooded and contains abundant wildlife (chiggers).

The Barite Industry

History

The first reference to barite mineralization in the area was made in a report on lead mines in Washington County in the early 19th cen-tury. The mineral was reported to occur in association with galena and was not recovered. The first sale of barite was recorded in 1872; production data indicate that mining has been continuous from 1872 to date.

Current Production

Missouri ranks second to Arkansas in quantity of barite produced and ranks first in value of production because of the higher grade of barite marketed. Since 1872, Missouri barite production totals over 8 million tons valued at more than $74 million. Annual production of barite from the Meramec Basin is shown in table 3. Yearly output was highest in 1956 when 381,642 tons valued at nearly $4.5 million was produced.

TABLE 3.- Barite production in Meramec River Basin, 1942-1961

Year	Shipments, short tons	Value
1942	146,270	$ 943,131
1943	124,147	872,044
1944	150,748	1,121,678
1945	225,467	1,841,959
1946	270,850	2,168,067
1947	291,619	2,405,249
1948	278,071	2,413,802
1949	186,891	1,497,985
1950	212,736	1,924,520
1951	281,895	2,697,200
1952	303,651	2,915,558
1953	318,720	3,213,816
1954	311,407	3,028,899
1955	363,692	4,003,842
1956	381,642	4,461,955
1957	317,350	3,938,486
1958	199,268	2,546,693
1959	296,478	3,923,651
1960	180,702	2,587,820
1961	237,669	3,180,988
TOTAL	5,079,273	$51,687,343

Figure 6 graphically illustrates tonnage and value of barite shipments in the Meramec Basin for the period 1942 through 1962. The curves reflect general business conditions during the period. Eight companies mined and processed barite in the Meramec Basin during 1961.

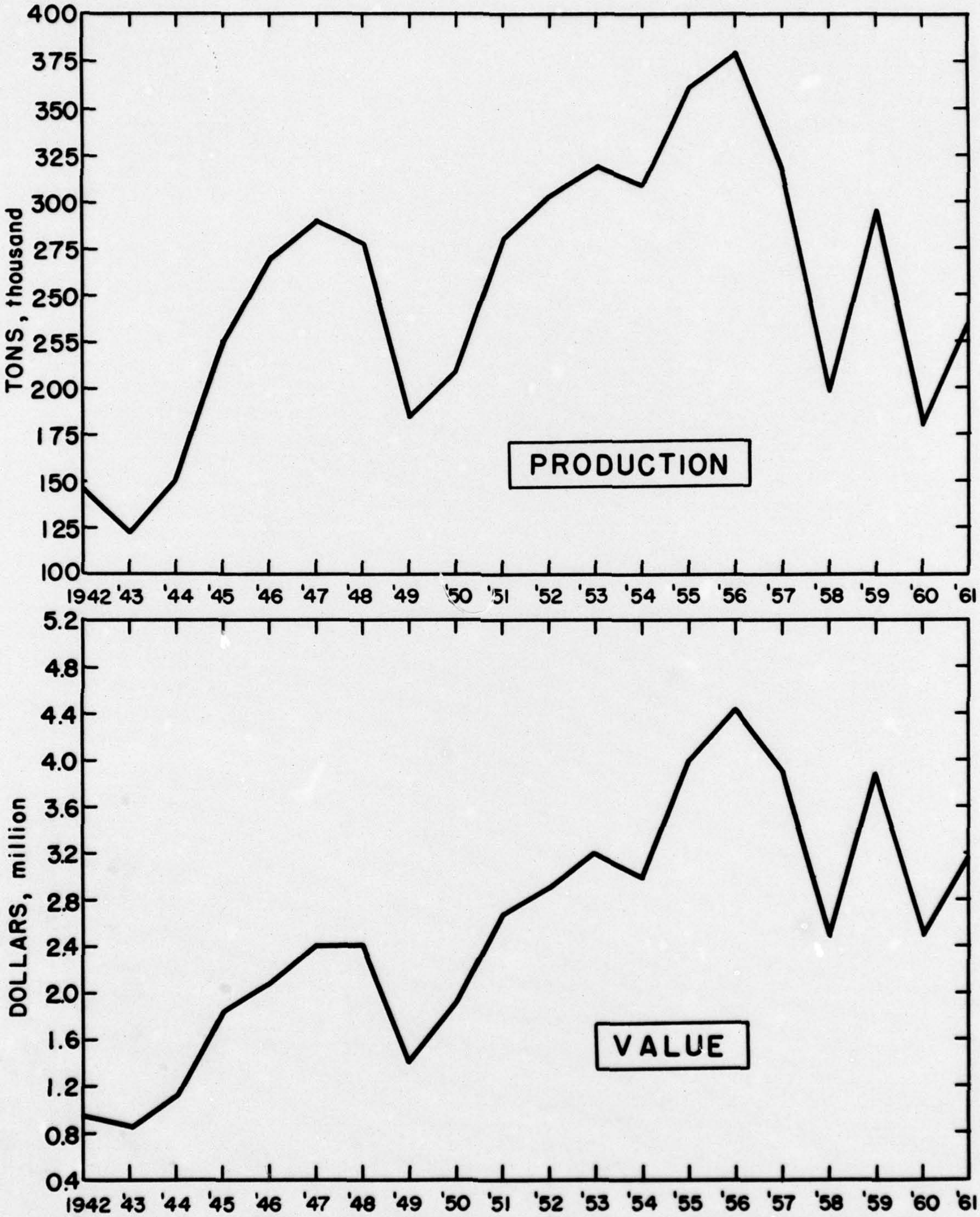


FIGURE 6. - Barite production and value in the Meramec River Basin 1942-1961.

Uses of Barite

Chief uses of barite, in order of importance, are drilling muds, glass, rubber and paint filler, and chemicals. The high specific gravity, low cost, freedom from detrimental impurities, and inert property make barite a very desirable weighing agent for drilling muds. The glass-making industry is the second largest consumer of barite. Barium salts are used to add weight, impart greater refraction, higher luster, and elasticity in glass. Barium compounds contain properties that make them valuable in many chemical and industrial processes; thus, these industries consume a large quantity of barite.

Exploration, Mining, and Milling

Barite mineralization occurs at or near the surface in the Meramec Basin; consequently, scientific exploration techniques are not extensively utilized. Backhoe trenching is the most widely used method of delineating new barite deposits. Some operators use old pits dug by hand miners as a guide to potential barite ore and obtain mining rights to the areas.

The shallow depth and wide distribution of the barite deposits resulted in simple and primitive mining methods. Early mining was done by individuals on land leased from local farmers. Though output per man was low, total production was high due to the large number of people actively mining barite. Only rich deposits were mined and ore was hand picked. Barite was mined in this manner until the late 1930's.

With the advent of mechanized mining, individually organized pits and primitive techniques slowly disappeared from the scene. As market demand increased in the twenties, small washing plants and steam-driven power shovels were introduced in the district. Mechanization was further intensified during World War II.

Currently, all barite produced in the Meramec Basin is mined by open pit methods. Where barite ore is found at depth, the overburden is stripped with power-drawn scrapers; however, mining at most pits is initiated at surface exposures. The average depth of the ore mined in the district is approximately 20 feet. Drilling and blasting are used to some extent to mine barite occurring as a cementing mineral in rock breccia. The ore is loaded by diesel or electric-powered shovels into diesel trucks and hauled to separation plants in the immediate vicinity of the pits. Road building and maintenance for haulage to plants are expensive items, especially in wet weather.

The mineral is separated from the gangue in double log washers and jigs. Mine-run ore is dumped into a hopper, then passed over a stationary or rotating grizzly 2/. The ore is constantly sprayed with water. Oversize is carried on conveyors to a waste pile; undersize feeds into the log washer to be washed and cleaned. Coarse gravel is rejected as the ore passes through a specially designed trommel screen; undersize from the trommel screen enters a jig where it is further cleaned and classified. Jig concentrates are shipped to grinding mills. Washer plant capacity in the district varies from about 350 to 1,000 tons per day.

2/ Stroud, R. B. Trip Report of May 24, 1962.

Water Consumption and Stream Pollution

Water requirements for washer operation are tremendous and availability of water determines plant capacity. Water is stored by constructing ponds or building dams across gulleys and ravines. Stored water is frequently supplemented by pumping from permanent streams or deep wells.

A washer plant having a capacity of 800-1,000 cubic yards of ore-bearing residuum in a 24-hour day, producing around 100 tons of barite concentrates, will use a minimum of 1,000 to 1,200 gallons of water per minute 3/. Of the total water used, 800 to 900 gallons is recirculated; new water is required to replace the loss.

Water and waste products from washer operations and jig plants are not discharged directly into streams. The water is not chemically contaminated, but does contain colloidal particles of silt and clay in suspension. The plant and mill discharge passes into settling ponds or basins ranging from five to ten acres in size from whence clarified water is released, and it carries no chemical contaminants.

3/ Muilenburg, G. A Barite Mining in Missouri. Missouri Geological Survey, 1948.

Future Production Outlook

Reserves

Current reserves of barite in the Meramec Basin are not known. Due to the extremely competitive nature of the industry, individual companies are reluctant to allow publication of data pertaining to their

potential reserves. However, it has been reported that large barite reserves do exist in the district. Muilenburg 4/ estimated reserves at

4/ Work cited in footnote 3.

a minimum of 15 million tons, based on the assumption that one-third of the total available mineralized acreage is proven productive. Average recovery was assumed at 150 pounds of barite concentrate per cubic yard of material mined.

Technology

Future development in the barite industry is difficult to predict. Technological advances can be expected to continue, resulting in more automation in plants and mines. Larger mining equipment will be introduced as market demand increases significantly.

Research with barium compounds is prosecuted vigorously; nine technical papers were published in 1960 5/. The National Bureau of Standards

5/ Minerals Yearbook, 1960, Vol. I, U.S. Bureau of Mines

discovered a series of barium niobates containing one of several rare-earth elements and iron oxide that possessed both ferroelectric and ferrimagnetic properties. These compounds have potential application in the electronics industry.

Extractive metallurgy research indicates that an economical recovery of barite can be obtained in treating fines from settling ponds of present and past operations. Widespread application of this process could increase tremendously the reserve potential of the Meramec Basin and extend the life of the industry.

Effects of Reservoirs on Barite Resources

Four headwater, two major, and one intermediate reservoirs will inundate land containing barite mineralization. The affected area may or may not contain commercial deposits. No estimate of quantity of barite lost due to inundation was made for this investigation. Should reserve data be released by industry to the Bureau of Mines, then subsequent detailed field work could establish the loss of barite reserves attributable to reservoir construction.

Current active barite mining operations will not be affected by proposed reservoirs since the exploited deposits are situated above flood control elevation. However, it must be pointed out that should demand for barite increase, then more operators would be engaged in mining and this would necessitate a reevaluation of the reservoir-mineral industry cause and effect relationship. Known barite deposits and/or prospects in the Meramec Basin that would be affected by the proposed reservoir construction are summarized in table 4.

TABLE 4.- Reservoir data and barite mineralization

County	Reservoir	Stream	Approximate dam height in feet	Elevation of flood control in feet	Known deposits and/or prospects inundated
Crawford	Meramec Park	Meramec River	175	701	2
Franklin	Virginia Mines	Meramec River	115	577	7
Franklin	Union	Bourbeuse River	150	651	2
Jefferson	Pine Ford	Big River	140	595	3
Washington	Pine Ford	Big River	140	595	7
Washington	Little Indian	Little Indian Creek	100	722	1
Washington	Courtois	Courtois Creek	75	834	1

Economics of Barite Industry

In order to assess the future of the barite industry and determine its possible economic impact on the Meramec Basin, it is necessary to study historical trends and relationships affecting this industry. The markets for barite produced in this area are national in scope and, as such, the review of the industry cannot be restricted to only the Meramec Basin of Missouri.

Another factor that must be considered in making an economic analysis of the barite industry of Missouri is the fact that the major barite producers use the commodity in manufacturing drilling muds. In other words, the barite produced in Missouri, to some extent, has a captive market.

Relation to Economy of Basin

In 1960, the barite industry employed 327 workers in Washington County in mining operations and 71 in grinding plants or mills. The total employment represented over 90 percent of the workers engaged in mining activities within the county and 11 percent of the total civilian labor force of the county. An estimated $1.3 million was spent in payrolls by the industry, with employees having an estimated average annual income of $3,600. Expenditures on supplies and capital equipment were estimated to be over $1.5 million in 1960. Through payments in wages, expenditures for supplies, construction, utilities, etc., the barite industry indirectly supported an additional 6 percent of the total civilian labor force. Thus, directly and indirectly, this industry accounted for almost one-fifth of the labor force in Washington County.

In Jefferson and St. Louis Counties, 58 employees were engaged by the barite industry in 1960. Most of these were employed in grinding plants in St. Louis County.

Supply 6/

6/ Supply is defined as mine or plant production of primary or crude barite plus imports for consumption.

The Meramec Basin of Missouri was, in 1960, the second largest domestic barite-producing area and led the Nation in value of shipments. Average unit value of Missouri barite in 1960 was $14.32 per ton, compared with a national average of $12. Barite produced in the Basin accounted for almost 13 percent of the total domestic supply in 1960; this compares with 20 percent in the record year 1956. Imports of barite have significantly altered the traditional patterns of supply. In 1950, imports represented only 8 percent of supply; a decade later in 1960, this figure had increased to over 45 percent.

Of significance to the future of the industry, barite produced in Meramec Basin is of higher grade than that generally produced in the rest of the United States. As demonstrated by fig. 7, a trend appears to be developing whereby the area's barite industry will become less dependent on oil and gas well drilling as a primary market for its products. Other uses that require high percentages of barium sulphate will become more important to the Basin's barite industry.

Demand 7/

7/ For the United States, demand is defined as consumption plus imports for consumption of primary or crude barite. Barite sold or used is considered as demand for Missouri.

Demand for Missouri barite has not kept pace with total national demand. From 1929-1960, demand for Missouri barite increased at an average annual rate of 1.4 percent; national demand increased 4.3 percent per year. Competition from domestic barite produced in Arkansas and imported barite has resulted in the lower rate of growth. Demand continues to be strong for Missouri barite for use by glass, paint, chemicals, and rubber industries.

Price

Prices of Missouri barite have remained unchanged since 1957. Until that time, prices had shown a steady increase.

TABLE 5.- Range of prices of Missouri barite for selected years, per short ton f.o.b. cars and/or mine

	1950	1955	1957	1961	
Crude ore, minimum 94 percent $BaSO_4$, less 1 percent Fe	$ 9-$10	$13-$14	$16-$18	$16-$18	f.o.b. cars
Water - ground and floated - bleached	$37-$38	$41-$47	$45-$49	$45-$49	car lots, f.o.b. mine

The static pattern of prices which has developed over the last five years seems to be a direct result of competition from imports. In May 1961, prices of imported crude barite used for oil-well drilling

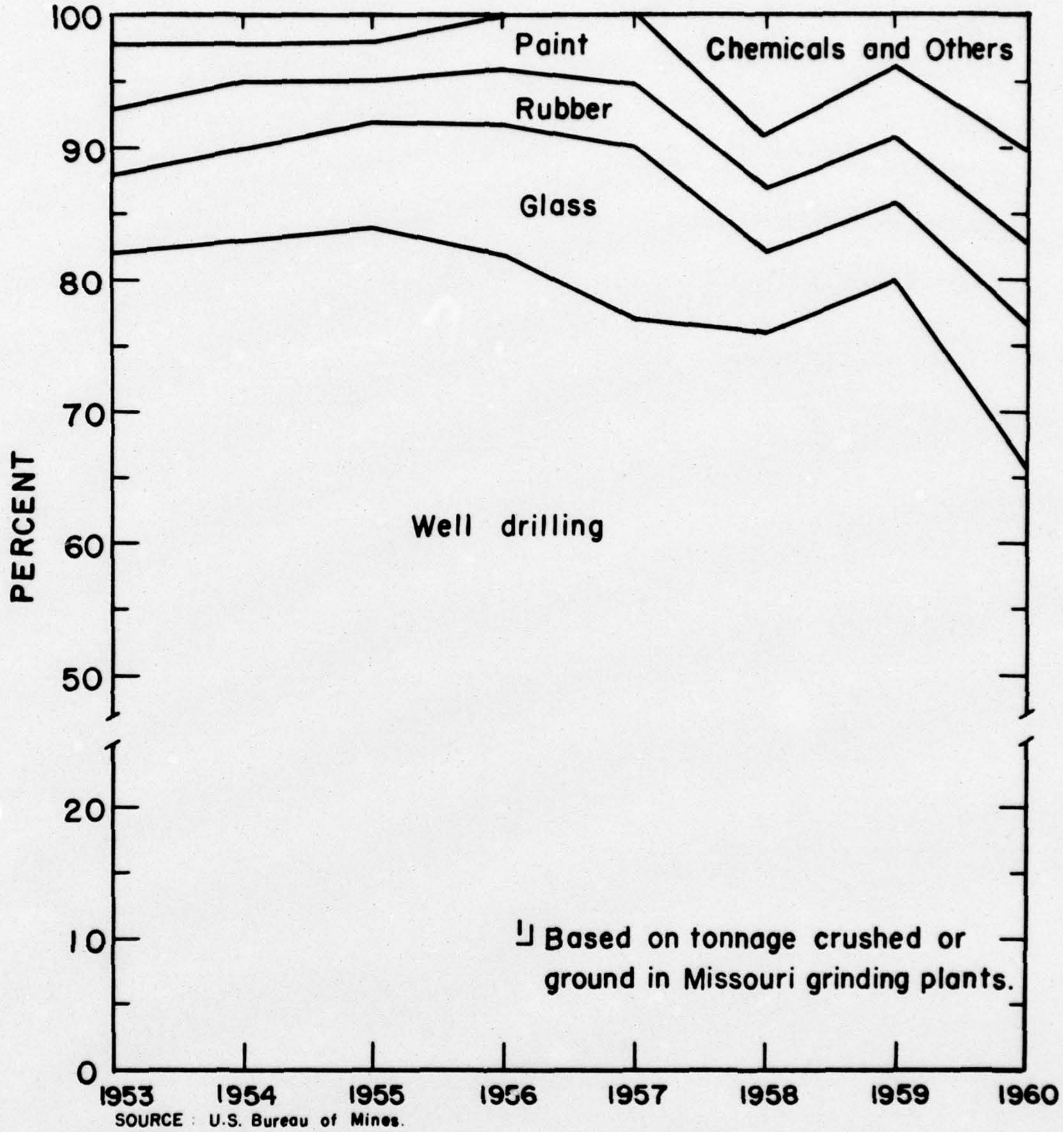


FIGURE 7. -Percentage disposition of barite produced in the Meramec Basin by consuming industry, 1953-1960.[1]

were reduced by about 20 percent. Continuation of this trend could have direct repercussion on Missouri barite which is used for this purpose.

Transportation

In 1960, shipments of crude barite to grinding plants in Texas, Kansas, and other States were made by rail; shipments to plants in Missouri were hauled by truck. Distribution of the ground barite from Missouri plants is accomplished almost exclusively in specially designed railcars.

Projections

The following assumptions were made in calculating future levels of barite production and employment in the industry.

1. Gross National Product will continue to increase at least 3 percent per year.

2. New technology for recovery of the commodity will not significantly change present processes.

3. Substitutes for barite in its major uses will not be developed.

4. Output per man will not change significantly.

5. Foreign trade between U.S. and foreign countries supplying barite will not be restricted.

6. At the present rate of production (1960), estimated reserves of barite will be depleted about year 2000.

Continued replacement of Missouri barite used in well drilling by competitive domestic sources and imports will adversely affect that industry. However, this could give the Missouri barite industry the opportunity to concentrate on production of higher grade barite for use in glass, rubber, paint, and chemical industries. A development such as this might materially extend the economic life of Missouri barite.

From 1929 to 1960, demand for Missouri barite increased at an annual rate of 1.4 percent; from 1960 to year 2000, demand for Missouri barite should increase at an annual rate of 1 percent. This would continue the trend of recent years and result in 270,000 short tons being sold or used by Missouri producers in 2000, approximately 5 percent of total estimated domestic demand of 5.3 million tons for that year. Production of Missouri barite will continue the downward trend, comprising less and less of the total domestic demand.

During the years between 1960 and 2000, employment in the barite industry should remain between 400 and 500. The many variables affecting employment make it impossible to present other than a range of employment. Declining production could have adverse effects on the economy of Washington County, especially the city of Potosi. Severity of reduced employment in the barite industry will, of course, depend on availability of other employment opportunities.

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Refractory Clays in Meramec River Basin

Introduction

The clay-producing area of the Meramec Basin lies south of the Missouri River and in the north-central Ozark region in a locality known as the "Southern Clay District of Missouri" (fig. 8). Counties comprising the district are Crawford, Franklin, Gasconade, Maries, Osage, and Phelps; all are either partly or entirely within the Meramec Basin. Refractory clays are the only type mined. In the central and western parts of the Meramec Basin, refractory clay mining represents the chief mineral industry. Transportation facilities consist of a network of State and Federal highways and two railroads. The St. Louis-San Francisco Railroad traverses the southern edge of the district, with shipping points at Rolla, St. James, and Cuba; the Chicago-Rock Island-Pacific Railroad traverses the central portion, with shipping points at Belle, Bland, Owensville, Rosebud, and Gerald.

Geology

Stratigraphy

The clays in the southern district are in the lower part of the Cherokee group of the Pennsylvanian system. The basal member of this group is the "Graydon" formation, named by Winslow 8/. In the district,

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8/ Winslow, Arthur. Lead and Zinc Deposits. Missouri Geological Survey, v. VII, sec. 2, 1st ser., 1894.

the formation contains chert conglomerate and sandstone beds. The conglomerate is composed of weathered chert derived from underlying formations. Lenses of fine-grained, hard, locally quartzitic sandstone are common in the lower part of the formation. Excellent exposures of the "Graydon" chert conglomerate and sandstone can be observed in the Cove Hill locality east of Mount Sterling, Gasconade County 9/.

9/ McQueen, H. S. Geology of the Fire Clay District of East Central Missouri. Missouri Geological Survey, Vol. 28, 2nd ser., 1943.

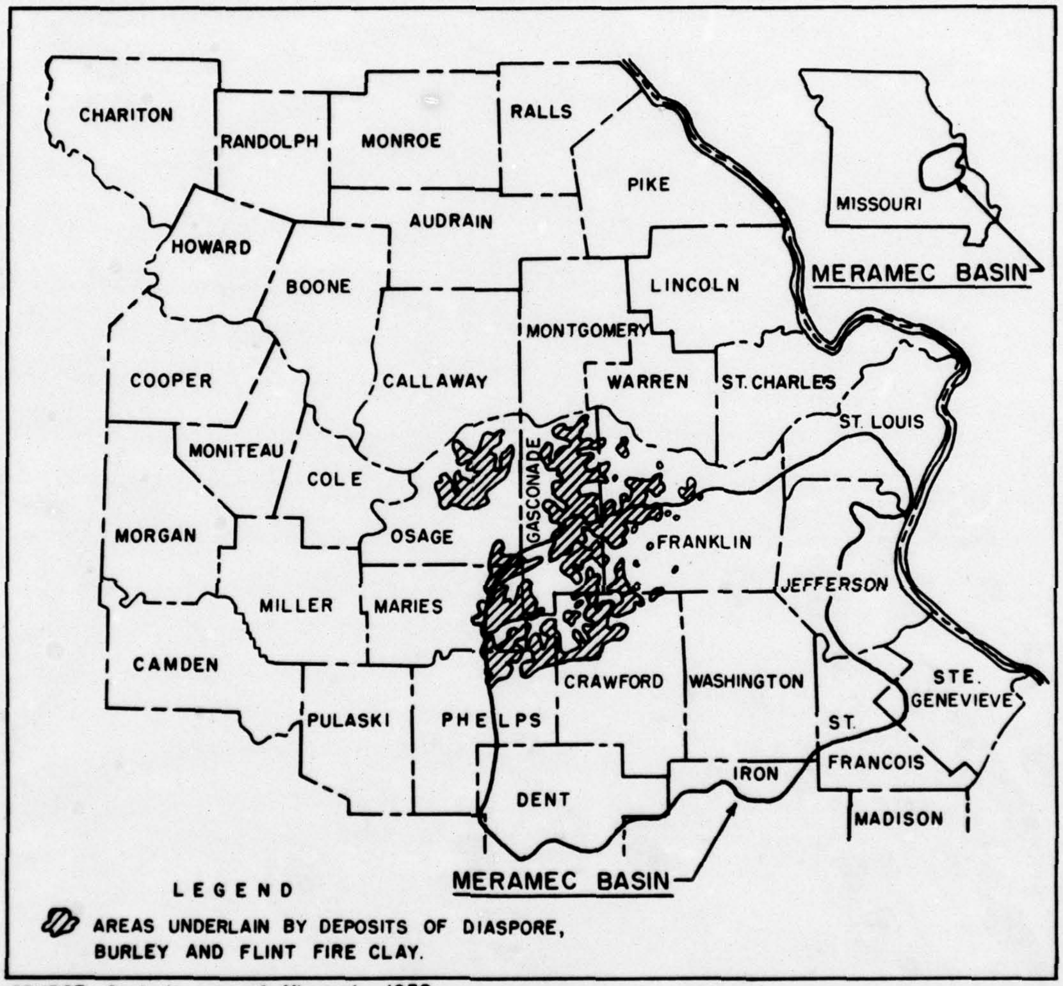
Mode of Occurrence

Diaspore, burley, and flint clays, in addition to small quantities of plastic clays, are mined in the southern clay district. They occur in inverted cone-like sink holes surrounded by a "rim rock" sandstone of the Graydon formation 10/. The individual deposits vary in size and

10/ Work cited in footnote 9.

depth. The clays are believed to have been derived from weathering of argillaceous dolomite and limestone of the Eminence and Gasconade formations. Soluble minerals were removed and the clay minerals left behind as a residuum filling in cavities and other solution structures. Occurrence of different types of clays within an individual deposit is variable; for example, all deposits contain flint clay, but not all contain burley or diaspore clays.

Flint clays are usually found near the surface; the burley and diaspore clays are associated with the deeper zones of the deposits.



SOURCE: Geologic map of Missouri - 1939.

FIGURE 8.- Refractory clay resources in the Meramec Basin, Missouri.

Topography

The topography of the southern clay district can be described as rough in areas adjacent to major streams and gently rolling in the uplands; maximum relief is about 700 feet. The district is predominantly a partly timbered grazing and agricultural area. The major stream of the district - within the Meramec Basin - is the Bourbeuse River. According to McQueen, individual deposits of clay have little if any relation to topography of the area; thus topographic features cannot be used to detect their presence.

Types of Refractory Clays

Characteristics

A popular definition of refractory clay is as follows: "An earthy material that contains silicate and alumina (kaolinite), is vitreous when fired at a sufficiently high temperature, and can be rendered more or less plastic when pulverized and mixed with water". The chemical composition of commercial clays ranges from pure kaolinite to an earthy substance in which the mineral kaolinite loses its identity. A system of grade control based on chemical and physical properties is utilized by clay miners of the district. Many clay types have evolved from this grading practice. It is not the purpose of this report to evaluate the many individual grades, but to limit the discussion to the basic refractory clays mined in the district, diaspore, burley, flint, and plastic.

The most significant single property of refractory clays is the pyrometric cone equivalent (P.C.E.) (table 6). It is determined by

comparing the softening behaviour of a clay sample subjected to a standard time-temperature schedule with that of standard "cones" (actually triangular pyramids). Moreover, high-temperature load and spall tests conforming to ASTM specifications C-12 and C-122 are prerequisites for good refractory clays.

TABLE 6.- Refractory ratings

P.C.E. range	Temperature	Type of refractory
33+	3169^{o} F @ 270^{o} heating rate per hour	Super duty
31-33	3061^{o} F.	High duty
30-31	3029^{o} F.	Low duty
15-30	2606^{o} F.	Serviceable

Source: Mineral Facts & Problems, U.S. Bureau of Mines

Diaspore clay

Commercial quantities of diaspore clay in Missouri are restricted to the southern clay district. Chemical composition of diaspore clay ranges from about 60 percent to more than 70 percent alumina. The clays are largely aluminum hydrates ($Al_2O_3 \cdot H_2O$) and have a pyrometric cone equivalent of 36 or higher. The chief impurity is iron oxide - its presence determines color of the clay. Ceramic products manufactured from diaspore clay are noted for their ability to withstand high temperature.

Burley clay

Burley clays are so named because they contain rounded particles ranging in size from small oolites or shot-like particles to 1-inch nodules. Chemical composition of the clay ranges from about 45 percent

to 60 percent alumina. The pyrometric cone equivalent of burley clay is about 34. Variable composition of the burley clay within the above limits is due to its secondary origin. Both burley and diaspore clays are believed to be gradational products resulting from alteration of hydrous aluminum silicates to the hydrated oxides of alumina produced by chemical action of circulating ground water. In 1960, the entire output of burley clay in Missouri was mined in the southern clay district.

<u>Flint clay</u>

Flint clay is the predominant clay in the southern clay district and is characterized by its hardness, lack of plasticity, smooth texture, and conchoidal fracture. Flint clays occur in a wide range of colors; white is most common and is the color most desired by processors. Organic matter and iron act as coloring agents. Flint clay has an average chemical composition of about 38 percent alumina and 43 percent silica and a pyrometric cone equivalent of 33 to 34. These clays are basically kaolinitic, but usually include other minerals such as halloysite and illite, and both organic and inorganic impurities.

<u>Plastic clay</u>

Plastic clay is characterized by its moldability and capacity to bond nonplastic material. It contains 25 to 33 percent alumina and 49 to 56 percent silica.

The Clay Industry

History

According to Wheeler 11/, production of flint clays for refractory purposes in the southern clay district began in 1883. For many years, the diaspore clay was discarded as a waste product of clay mining operations in the district. The presence of the mineral diaspore in Missouri clays was identified by Wherry 12/. Refractories manufactured from diaspore clay came into use in 1914. The first report specifically describing the fire clays of east-central Missouri was prepared by Wheeler 13/.

11/ Wheeler, H. A. Clay Deposits, Missouri Geological Survey, 1st ser., v. XI, 1896.

12/ Wherry, E. T. Diasporite in Missouri. Amer. Miner, v. 2, 1917.

13/ Work cited in footnote 11.

Current Production

The production of all clays (refractory and miscellaneous) and clay products constitutes an important mineral industry in Missouri. Since 1899, Missouri clay production totals about 55 million tons valued at more than $157 million. Missouri ranked fifth among the States in value of clay output for 1960.

Refractory clays for nine processing plants located in Audrain, Calloway, Gasconade, and St. Louis Counties were mined in the southern clay district of Missouri in 1961. A minor quantity of special refractory clay was utilized by the chemical industry. Annual production of refractory clay for the counties in the Basin is shown in table 7. Value of clay mined in the Basin reached a peak in 1953 when $4.6 million worth of clay was sold or used, representing 46 percent of the total value of refractory clays produced in the entire State in that year. Production value of clay in 1961 declined to 43 percent of Missouri's total because demand for clay products weakened. The production curve shown in fig. 9 illustrates tonnage and value of all clays produced in the Meramec Basin for the period of 1952 through 1961. The curve reflects general business conditions during the period.

TABLE 7.- Refractory clays used or sold in the Meramec River Basin

Year	Production (short tons)	Value
1952	645,011	$4,154,623
1953	607,017	4,669,760
1954	498,132	2,164,980
1955	522,658	2,488,737
1956	629,626	3,167,465
1957	635,058	3,109,870
1958	550,379	2,756,208
1959	736,457	3,262,421
1960	727,508	3,444,123
1961	451,212	1,756,145

Source: U.S. Bureau of Mines.

Exploration, Mining, and Transportation

During early development of the district, discovery of clay deposits was based on surface evidence such as exposure of sandstone rimrock and presence of diaspore or flint clay float. Most of these deposits have been found and depleted. Location of the deeper deposits, having no surface indications, requires modern drilling equipment and scientific exploration techniques. Auger drilling is utilized extensively, especially to explore for clay deposits over an extensive area. Major refractory product companies prefer to use portable rotary and diamond drills to delineate deposits.

Mineral leases are held by the major processing companies; royalty payments based on quality of the clay are made to the property owner. The general schedule of royalties paid for various types of clay is shown in table 8.

TABLE 8.- Schedule of royalty payments in Missouri, by type of clay

Types of clay	Royalty per short ton
Plastic and semiflint (Mexico)	$ 0.10
Plastic and semiflint (New Florence)	0.25
Flint (Southern Fire Clay District)	0.25
Burley	1.00
Diaspore	2.50-3.00

Source: Rollman, H. E., and Harvard Eng. Sources of Refractory Raw Materials and Refractory Markets in South-Central United States. U.S. Bureau of Mines I.C. 7950.

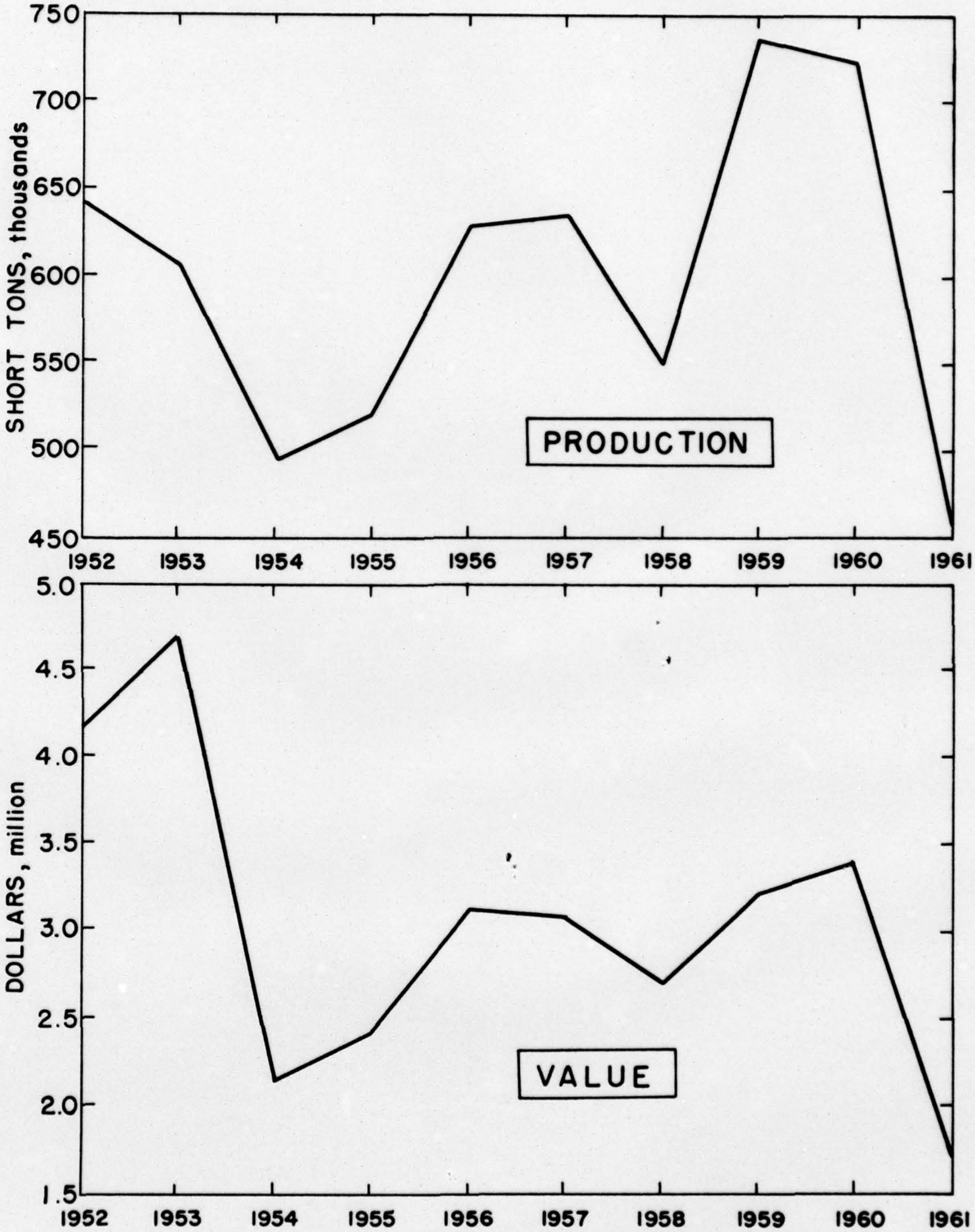


FIGURE 9.—Clay production and value in the Meramec River Basin 1952-1961.

Currently, all clays produced in the Meramec Basin are mined by the open pit method. After a clay deposit has been outlined by drilling, heavy tractor-scraper equipment is used to strip the overburden. In the southern clay district, the overburden consists of red or yellowish residual clay, soil, and gravel. It is usually not excessively thick - averaging approximately 5 feet. After removal of overburden, the exposed clay is drilled with pneumatic drilling machines and blasted with explosives. Power shovels or draglines are used to load the clay into trucks.

Most of the clays produced in the southern clay district are mined by contractors and trucked to stockpiles situated either at a rail center or a centrally located point in the mining area. Common practice throughout the district is to allow the clay to remain in the stockpiles for a period from one to three years. Since chemical and physical properties of the clays differ from one pit to another, the mining contractor must stockpile clay in separate piles. In this way, it is possible for the ceramic engineer to blend the clays in order to produce the high quality refractories that are in demand.

The clay is hauled to processing plants in Audrain, Callaway, Gasconade, and St. Louis Counties either in tandem trucks by a trucking contractor or gondola cars by railway. The volume of material transported determines the method utilized. Usually, large companies contract with railroads for shipment to their plants; small companies depend on truck haulage.

Currently, the only clay beneficiation method utilized in the district is the weathering process resulting from the stockpiling practices. It is believed that the exposed clay undergoes a chemical reaction which enhances the value of the end product. However, research in beneficiation is being prosecuted vigorously in an effort to reduce alkalinity of the subgrade refractory clays.

Water Consumption

Water requirements at the various pits are low; in fact, the presence of large quantities of water precludes economic mining operations. As a consequence of the stockpiling practices in the district, clay mining is normally scheduled during seasons of relatively dry weather.

Future Production Outlook

Reserves

An estimate of clay reserves in the southern district of the Meramec Basin was not available for this report. However, McQueen calculated that an area of 626 square miles in the district is underlain by potential clay horizons 14/. Undoubtedly, some of this area

14/ Work cited in footnote 9.

has been extensively prospected, and perhaps most of the clay deposits at or near the surface have been discovered and depleted. The discovery of additional clay deposits is dependent on a thorough understanding of geological environment under which the mineral formed.

Development of new tools and techniques for clay exploration will tax the imagination of engineers and geologists for many years to come.

The future of the district might best be summarized by quoting portions from McQueen's publication 15/.

15/ Work cited in footnote 9.

> It stands to reason that in an area of comparatively small sink-hole type deposits, varying in size, in depth, and in the tonnage of the contained clays, and in an area that has not been systematically prospected or studied in detail geologically, no estimate of the reserve tonnage can be made. For the same reason, no accurate future of the district can be predicted. The writer believes, however, that the continued advances in ceramic technology, and the application of geology to the problem will bring fruitful results. Certainly, all of the deposits have not been found by any means. In many large areas with practically no surface expression of a deposit, there has been no systematic prospecting. Until such intelligent prospecting, adapted to and comparable to the scale of consumption, is employed, until all the areas have been fully explored, until that time, then certainly it cannot be said that the district has reached its maximum of development.
>
> The high alumina diaspore clay occurs in local sink-hole type deposits. The alumina content of this clay is variable and the size and shape of the deposits of mode and occurrence are factors that preclude large scale operations. While the actual tonnage of unmined diaspore clay is not known, it is apparent to any casual observer that the tonnage being mined for use in the fire brick industry at the present time vastly exceeds the present rate of discovery. Although additional deposits will be discovered with modern methods of systematic prospecting, it is not believed that the tonnage of diaspore and associated burley clay will ever reach a comparatively large figure.

Table 9 is a summary of the number of square miles underlain by potential clay horizons for each county in the district and total county production for a 10-year period from 1952-1961.

TABLE 9.- Clay areas and total county production (1952-1961)

County	Number of square miles underlain by Pennsylvanian rocks	Total production Short tons	Total production Value
Crawford	65.7	68,675	$ 310,806
Franklin	90.5	264,721	1,052,436
Gasconade	207.1	4,414,304	23,106,147
Maries	95.4	424,421	1,981,092
Osage	110.0	504,170	3,324,671
Phelps	57.5	326,770	1,199,176
TOTAL	626.2	6,003,061	$30,974,328

Source: Missouri Geological Survey and Water Resources.

Technology and Trend

The future of clay mining is dependent on whether the manufacturer can meet requirements for higher quality refractory material demanded by current and future markets. The making of durable refractory products in the past was based on experience, with little regard to evaluation of chemical and physical properties of clay. An increased demand for metallurgical and industrial use resulted in intensive research on effects of impurities in clay and the crystalline structure of clay. As a consequence of this research, emphasis has been directed towards improving the end product through more precise quality control and tests and improved manufacturing techniques. The industry is supplying quality refractory material oriented toward severe operating conditions such as are encountered in nuclear reactors, jet engines, and missiles.

In the clay district, mining operations and material handling equipment will become further mechanized. Scientific exploration methods applied by trained personnel will result in discovery of clay deposits that heretofore have been overlooked. Rolla Metallurgical Research Center, Bureau of Mines, is currently engaged in a research project on beneficiation of subgrade refractory clays of Missouri. Laboratory results indicate that separation of free silica and extraction of the potassium ion from alkali clays is feasible.

Effect of Reservoirs on Clay Resources

Eleven proposed water storage reservoirs are located in the southern clay district of Missouri; of these, five are intermediate, four are headwater, and two are major reservoirs. Many known clay deposits, as well as a large area containing potential clay mineralization, may be lost to the refractory industry. In addition to the fact that the southern clay district contains the principal commercial deposits of diaspore clay in the United States, all the output of burley clay for Missouri in recent years was reported from this area. These valuable clays are not confined to any particular area or elevation in the district; hence, it must be assumed that some may be lost.

Clay technology is changing rapidly. Research on high sodium, potassium, and free silica clays has been prosecuted vigorously by the U.S. Bureau of Mines and others; results indicate that an economic separation of these impurities is commercially feasible. Consequently, deposits of clay that heretofore have been considered chemically unsatisfactory can now be re-examined for industrial and metallurgical uses. These clays are located at relatively low elevations and would be lost to industry if inundated.

Specifically, a large deposit of clay will be lost as a consequence of the construction of the Meramec Reservoir. Inquiry of two major refractory clay companies indicated that roughly 250,000 tons of clay reserves would be lost by other reservoirs located in the clay district. Precise data on clay reserves affected by the reservoir are not available because of type of occurrence of the individual deposits. Most are small and numerous; consequently cost of determining amount of clay in such deposits may be considerable.

The time limit imposed on this report precluded a detailed examination of the eleven proposed reservoir sites in order to ascertain their effect on clay deposits. A field reconnaissance program of each reservoir area should be conducted immediately after a location of the damsites has been tentatively established. This program should be coordinated with the interested clay mining and processing companies. Inundated clay deposits might be mined and the clay stockpiled outside the area. Areas of possible clay deposits or inferred clay reserves affected by the reservoirs would be explored by drilling. Table 10 summarizes a number of known clay deposits and/or prospects in the Meramec Basin that probably would be affected by proposed reservoir construction.

TABLE 10.- Reservoir data and clay mineralization

County	Reservoir	Stream	Approximate dam height in feet	Elevation of flood control	Known deposits and/or prospects
Crawford	Benton Creek	Benton Creek	No data	874	1
Crawford	Meramec Park	Meramec River	175	701	2
Franklin	Little Bourbeuse	Little Bourbeuse River	65	777	1
Franklin	Union	Bourbeuse River	150	651	1
Gasconade	Red Oak	Red Oak Creek	40	724	1
Gasconade	Dry Fork	Tributary of Dry Fork	40	882	1
Jefferson	Pine Ford	Big River	140	595	1

Economics of Clay Industry

In 1960, the U.S. Bureau of Mines published a detailed and comprehensive report on the clay industry of Missouri 16/. While the study was not on the Meramec Basin, the analyses and conclusions are applicable to that area. In addition, since it was a more thorough study than can be made at this time for the Meramec, portions are quoted below:

> The Missouri refractory industry is economically important nationally. Nearly one-fourth of the clay refractories produced in the United States are made in Missouri. Moreover, Missouri produces most of the higher grade refractories, about 62 percent of the high-alumina refractories, and 85 percent of the superduty refractories. The competitive position of the Missouri refractories industry is strong. The national market for clay refractories is expected to grow.

16/ Rollman, H. E. and Harvard Eng. Sources of Refractory Raw Materials and Refractory Markets in South Central United States, Bureau of Mines I.C. 7950.

In maintaining production of higher quality refractories, the major factor is development of the potential flint-clay resources of Missouri. The supply of flint clays is diminishing, and the discovery rate is declining. Annual demand for refractory clays in Missouri by 1975 is estimated at 2.6 million tons. Demand for fire clay refractories is expected to increase only half as fast as the total refractory demand. Demand for Missouri fire clays, however, is estimated to be growing at 2.4 percent per year, compared with a rate of 2.8 percent for all refractories. Missouri refractory clay is expected to reach 32 percent of the national total by 1975. The increased demand for high-grade refractories and for raising the quality of lower grade refractories will continue to drain already diminishing supplies of superduty clays. Refractory raw materials potentially available are unusable because of contained impurities; therefore, the long-term supply of high-grade clays will depend on research.

The supply of Missouri flint clays necessary for producing superduty refractories is increasingly difficult to maintain. The decrease in the supply of superduty clays could limit the capacity of the area to satisfy the long-term demand.

The movement of clays in Missouri for the production of refractories in 1957 was estimated at 66 million ton-miles. The average distance from the pit to the plant ranged from 35 to 40 miles. At most plants, materials were received by both truck and rail; at some plants, all materials were received by rail.

In 1957, 1.7 million tons of fire clay was produced from 148 mines in Missouri. Over nine-tenths of this clay was used for production of refractories.

Clays vary so much in chemical and physical characteristics, even within the class, that estimating requirements by type of clay is difficult. Approximately 57 percent of all clays used in Missouri for manufacturing refractories are plastic or semiflint clays. Flint clays represent another 30 percent, and burley, burley-flint, and diaspore comprise an additional 10 percent. The remaining 3 percent is bauxite.

Meramec Basin

Counties that are considered in the Meramec Basin study produced over 727,000 tons of refractory clays, valued at about $3.4 million, and represented 48 percent of the State's total 1960 output of refractory clays. It was not feasible to determine more specifically the amount produced within actual confines of the Basin.

In 1960, there were 495 employees in the Meramec Basin and adjacent area's clay industry. It is impossible to ascertain in which area or areas these employees reside. Employment in the industry in 1975 should range from 400-500 workers.

It is estimated that, in 1975, counties in the Basin will account for 35 percent of the estimated demand of 2.6 million tons of Missouri refractory clays. Estimates for periods beyond 1975 cannot be made because of lack of data on reserves.

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Iron Deposits in Meramec River Basin

Geology

Iron ore deposits in Missouri occur in two geologic horizons, and are usually grouped into two main types: (1) sedimentary limonite (field term for all hydrous iron oxides) and hematite associated with Paleozoic sediments; and (2) magnetite-hematite ore in Precambrian igneous rocks. Missouri State Geological Survey and Water Resources, in I.C. 147, further divided the sedimentary deposits into two groups: (1) brown iron (limonite), and (2) filled sink deposits.

Brown iron deposits were grouped as either primary or secondary according to origin. Primary deposits are believed to have resulted from direct deposition of limonite at surface temperature; secondary deposits, by alteration of pyrite and marcasite to limonite, then concentration of limonite fragments in a cherty clay residuum. All known secondary deposits were discovered as a result of limonite fragments found on the surface. It has been established that the concentration of limonite occurs in and above depressions in the bedrock. Size of deposit ranges from a few feet in diameter to several acres in extent and from a few feet to over 200 feet in thickness. Figure 10 shows the location of iron mines and prospects in the Meramec Basin.

Types of Deposits

Filled Sink Deposits

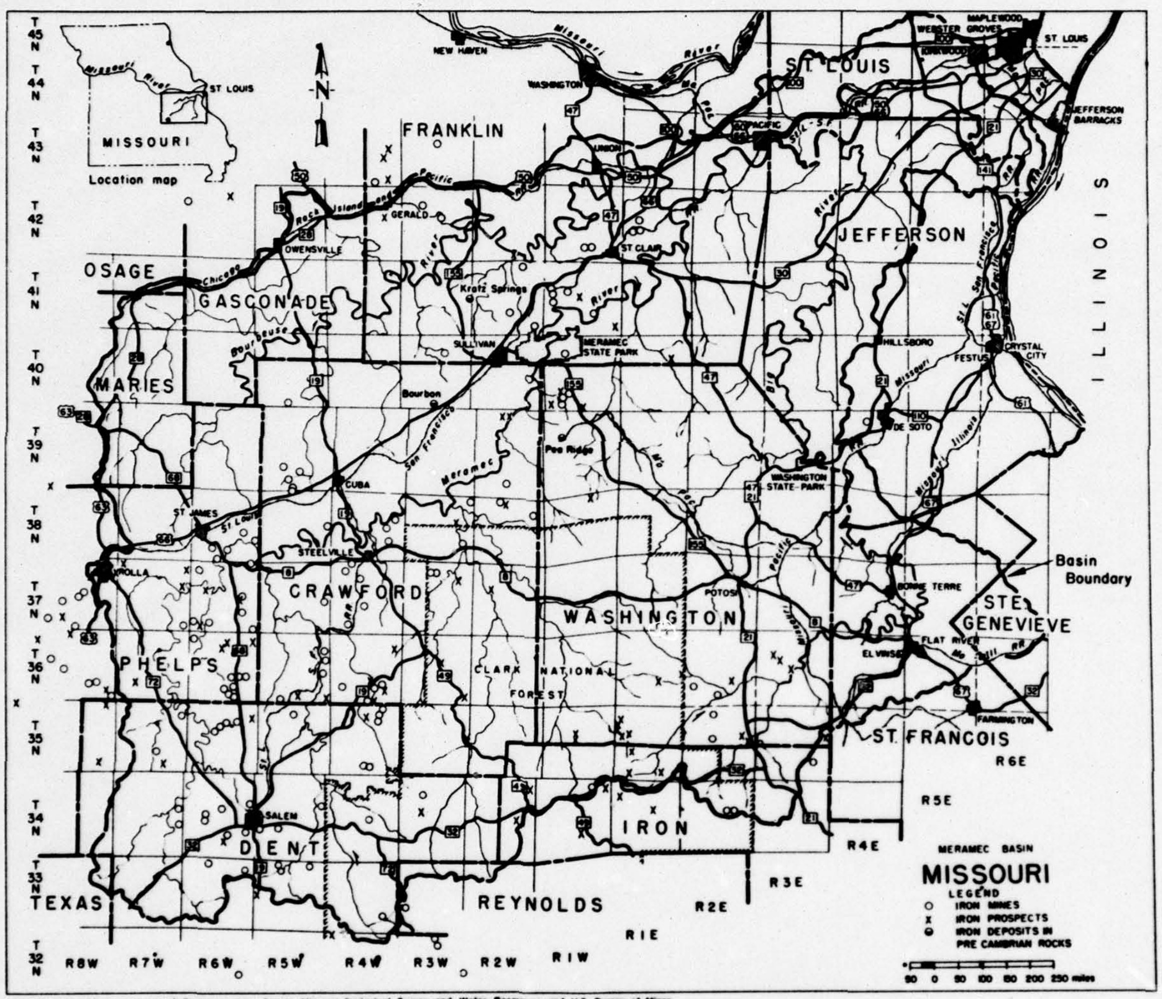
Crane (Missouri Geological Survey, Vol. X, 2nd Series) describes in detail the hematite ores of filled sink deposits which are concen-

trated in an area on the northeast flank of the Ozark dome. These ores occur in sink holes within the Gasconade and Roubidoux formations of early Ordovician age. Surrounding many deposits, a rim rock of Roubidoux sandstone is present showing centripetal dip. Ore masses of specular hematite are distributed irregularly within a deposit around claylike horses and blocks of bedrock. Soft, red hematite is the important ore in many deposits. Iron sulfides in the form of marcasite and pyrite, not considered iron ores, are found in the lower part of some deposits.

Precambrian Deposits

Precambrian rocks crop out in Iron, St. Francois, Madison, and adjoining counties. Deposits of magnetite and hematite occur in the Precambrian rocks in Missouri. The two minerals have been found as fissure fillings and irregular replacements in tuffs and agglomerates. After detailed study, members of the Missouri Geological Survey and others concluded that the deposits are of hydrothermal origin.

Exploration, starting in 1930, resulted in discovery of four or more large deposits of magnetite-hematite at depths ranging from 800 to more than 3,000 feet. During 1930, the Missouri Geological Survey began a magnetic survey which located a number of magnetic anomalies. Statewide magnetic and gravimetric maps were completed in 1943. During 1943-44, the U.S. Bureau of Mines drilled four holes on the southern part of the Bourbon anomaly, resulting in discovery of a large deposit of iron ore averaging more than 43 percent iron.



Adapted from US Army, Corps of Engineers map. Source: Missouri Geological Survey and Water Resources, and U.S. Bureau of Mines.

FIGURE 10.- Location of iron mines and prospects in Meramec Basin.

Anomalies at Pea Ridge and Floyd Tower, Washington County; Kratz Spring, Franklin County; Orla, Laclede County; St. Francisville, Clark County; Boss, Dent County; Levasy, Jackson County; and Avon, Ste. Genevieve County, have been prospected by drilling into Precambrian rock and magnetite or accessory minerals in gabbro were found. Substantial iron deposits were found at Pea Ridge, Kratz Spring, and Bourbon. Information regarding size or grade of the other discoveries is not available.

The Iron Industry

History

According to data collected by W. C. Hayes and published in Information Circular No. 14, 1957, by the Missouri Geological Survey and Water Resources, occurrence of brown iron ore or limonite was first recorded in 1673 by Marquette, a French Jesuit missionary. The first iron ore furnace was erected in 1815 at Stout Creek shut-in near Arcadia in Iron County, mainly for processing magnetite-hematite ores. During 1819 and 1820, the Harrison-Reeves furnace was built on Thicketty Creek, three miles southwest of Bourbon in Crawford County. In 1829, a furnace was erected at Meramec Spring, five miles southeast of St. James in Phelps County for treatment of hematite ores obtained from filled sink deposits.

The cumulative production from filled sink deposits by the end of 1900 totaled approximately 2.5 million long tons of ore. Mining of brown iron ores began around 1900 and, by the end of 1961, about 4.5 million long tons had been produced.

Mining of Precambrian ores at Iron Mountain, St. Francois County, began in 1844. In 1854, a blast furnace was erected at Iron Mountain, operated for about 20 years, then closed. Most of the ore was then shipped to St. Louis. Mining from Precambrian deposits has been continuous since 1870 except for the years 1907, 1933, and 1939-41 (Hayes).

Until about 1910, iron ore was hand mined; ore in sink deposits was loosened with hand picks and harder ores in Iron County were hand drilled and blasted. All ore was hand shoveled into mine cars or wagons for hauling to railroad cars or direct to a smelter. Since about 1910, there has been a gradual transition from all hand mining to almost 100 percent mechanical mining. Most of the iron ore mined in Missouri from filled sinks, prior to about 1912, was hauled an average of less than 10 miles to furnaces located at Meramec Spring, Phelps County, and Sligo, Dent County. Most of the ore from Precambrian deposits in Iron County was hauled by railroad to furnaces in St. Louis or farther east.

Iron ore production in Missouri to date totals about 15.5 million long tons, two-thirds of which has been mined from Precambrian deposits. During the past decade, yearly production of brown iron ore has averaged 110,000 long tons; during the same period, yearly production of Precambrian iron ore produced during the past ten years was mined from deposits at Iron Mountain, St. Francois County, by M. A. Hanna Co., Missouri Division. Production and value of iron ore from Meramec Basin - 1815 through 1961 - are shown in table 11 and figure 11.

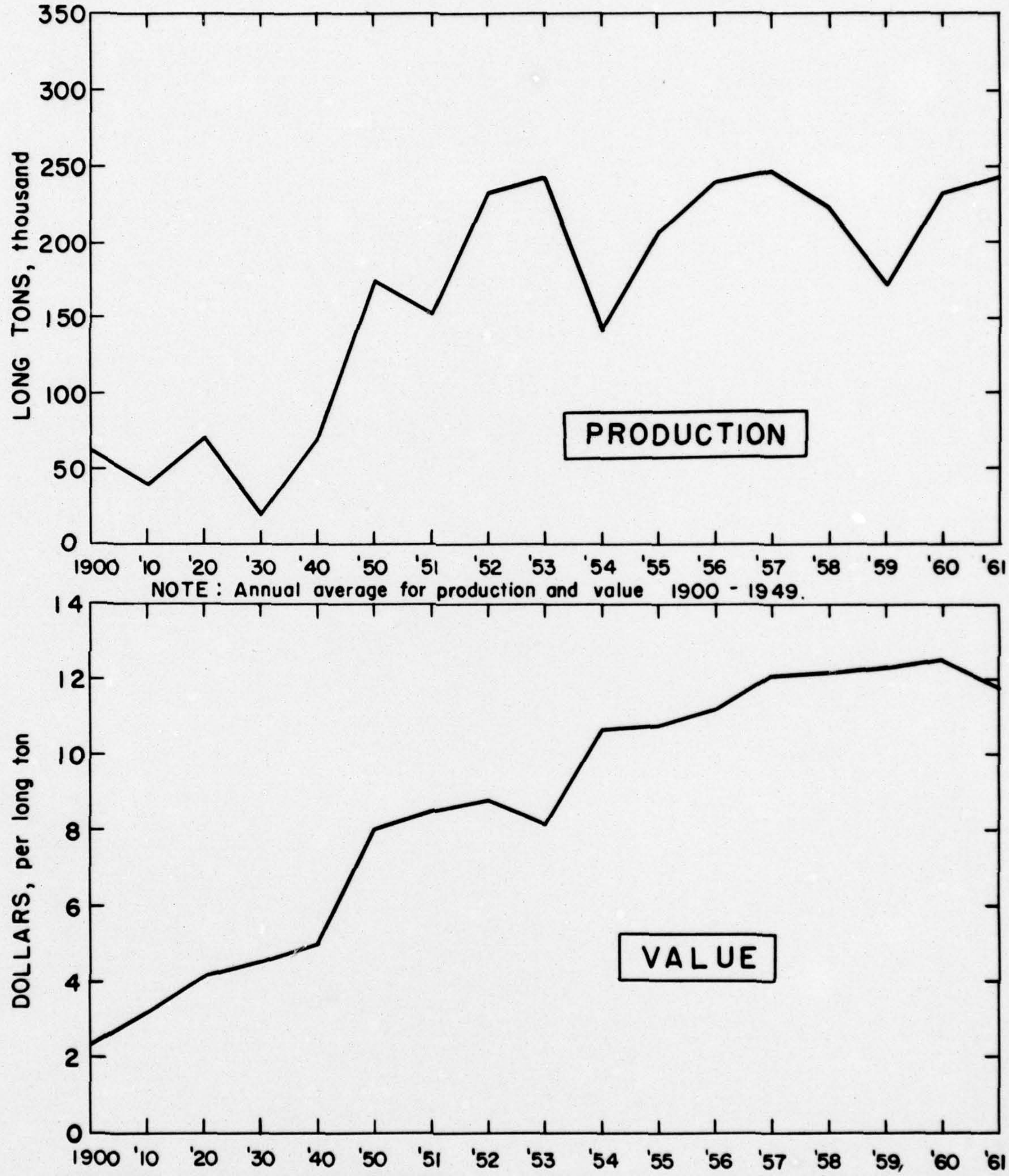


FIGURE 11.-Iron ore production and value in the Meramec River Basin 1900-1961.

TABLE 11.--Production and value of iron ore in Meramec River Basin, 1815-1961

Year	Long tons	Average value per long ton	Value
Prior to 1900	8,008,224	3.56	$28,478,462
1900 to 1909	636,063	2.35	1,497,794
1910 to 1919	411,225	3.24	1,322,700
1920 to 1929	749,279	4.12	3,088,941
1930 to 1939	232,426	4.48	1,040,235
1940 to 1949	788,943	5.01	3,952,883
1950	176,638	8.00	1,413,104
1951	154,947	8.45	1,309,020
1952	233,141	8.70	2,029,319
1953	240,021	8.04	1,929,845
1954	144,680	10.70	1,547,280
1955	208,007	10.80	2,245,852
1956	237,865	11.36	2,701,926
1957	248,562	12.02	2,987,966
1958	221,006	12.26	2,709,415
1959	174,000	12.37	2,151,585
1960	232,619	12.46	2,900,152
1961	240,740	11.80	2,841,919
TOTALS	13,374,386	4.94	$66,049,398

Current Iron Ore Mining in the Basin

In November, 1962, there was one iron ore producer a few miles outside the Basin boundary and one iron ore mine being developed in the Basin. At Iron Mountain, St. Francois County, M. A. Hanna, Missouri Division, is mining and upgrading about 2,000 long tons of iron ore per day. Total output of upgraded ore from the mine in 1961 was 240,740 long tons. During 1960, the company employed an average of 175 workers.

At Pea Ridge, Washington County, Meramec Mining Co. is constructing a plant that will have a capacity to beneficiate 12,000 long tons of

mine-run iron ore per day. Ore for the plant will be mined at depths ranging from about 1,700 to 3,000 feet below the surface. The company plans to have the mine and mill in production by the end of 1963 and will employ from 800 to 900 workers.

Exploration Within the Basin and Adjacent Area

Currently, most of the exploration for iron ore is concentrated in areas showing magnetic anomalies. Eighteen companies are doing exploratory drilling in southern Missouri; much of the exploration has been conducted within the Meramec Basin.

Drilling (churn, rotary, and core) is usually preceded by a geophysical survey. Several methods are used, but for iron ore deposits, prospectors prefer magnetic surveys. Often, an aerial survey is made before surface work begins.

Exploratory work in the Meramec Basin has resulted in the discovery of three iron ore deposits, Pea Ridge (being developed by Meramec Mining Co.), Bourbon (partially developed by American Zinc, Lead, & Smelting Co. and the Granite Steel Co.), and Kratz Spring (partially developed by St. Joseph Lead Co.). It has been rumored that other occurrences have been found in Precambrian rocks, but information regarding these deposits is not available at this time.

Mining Method

Iron ore is produced at the Iron Mountain mine of Midwest Ore Co. by a multilevel room and pillar method. The rooms are normally 25 feet high, 24 to 35 feet wide, and supported by 20-foot square

pillars. The operator has successfully adapted large earth-moving equipment to underground mining. Drilling is done with percussion drills mounted on two drill jumbos with enough height adjustment to reach the top of the rooms. The blasting agent is loaded into the holes from the drill jumbo platforms. Broken ore is loaded with a 3/4-yard electric dipper shovel into 8 cubic yard capacity diesel-powered gravity-dump trucks for haulage underground; all ore is crushed before being hoisted to the surface.

Beneficiation Methods and Water Use

In Missouri, iron ore is upgraded to produce marketable concentrates by either log washing and/or by gravity separation using one or two of the following: heavy media, tables, or jigs.

M. A. Hanna Co., Missouri Division, Iron Mountain, St. Francois County (a few miles east of the Meramec Basin), estimated new water requirements for its mineral-dressing plant to average 700 gallons per minute. The plant has a capacity of 2,000 long tons per day and obtains water from a nearby artificial lake. The lake contains overflow water from the tailing settling pond, water pumped from underground workings, and water from a small drainage area at the head of Charles Creek, a tributary of the St. Francis River.

Meramec Mining Co., Pea Ridge, Mo., estimated that peak demand for fresh water at the 12,000-ton-per-day capacity mineral-dressing plant (now being built) will be 1,250 gallons per minute. Fresh water will be obtained from the mine, or when necessary, from the Meramec River. The company is now laying a 10-inch pipeline from the

plant to the river for emergency use. Mill tailings will be discharged into a series of two or more settling ponds, and the water reused. Overflow from the settling ponds will drain into Little Courtois Creek, thence into Big Creek and the Meramec River.

Water overflowing from storage ponds into drainage streams might carry a small amount of silt and should not be chemically contaminated.

Future Production Outlook

Reserves

Reserves of iron ore in the Meramec Basin are estimated from published information and oral communications to be more than 400 million long tons, averaging more than 40 percent iron. The above estimate does not include other discoveries as yet of a confidential nature in the Precambrian rocks or the 150 or more sedimentary deposits on which definite data are not available.

Technology

The erection of one or more direct reduction plants in eastern Missouri might furnish a favorable market. Output of a direct reduction plant is acceptable as a substitute for scrap iron in open-hearth furnaces, provides a material to enrich blast furnace charges, thus reducing unit costs, or produces iron in areas where flux and fuels are not economically available. Similar plants have been successfully operated in Germany for more than 25 years, and since 1958, at Monterray, Nueva Leön, Mexico.

Effects of Reservoirs on Iron Industry

Proposed reservoirs in the Meramec Basin will not have an adverse effect on iron mining. None of the known near-surface deposits will be covered with water and, according to officials of Meramec Mining Co., the Precambrian deposits in impervious rock will not be affected by surface water.

Economics of Iron Ore Industry

The iron ore industry is a substantial contributor to the economy of the Meramec Basin. In 1960, the industry employed a total of 323 workers with an estimated payroll of $1.7 million; average annual income of all employees was $5,200. This figure does not include the exploration and development workers employed by the industry. Almost $3.6 million was spent on supplies and capital expenditures by companies producing ore in 1960. Additional millions were spent by Meramec Mining Co. in the development of the Pea Ridge iron ore project. In the future, this industry will significantly contribute to the economy of the Basin. When in full operation, Meramec Mining Co. will employ 800 to 900 workers, with a total payroll of $4-5 million.

The possibility exists of establishment of a direct iron ore reduction plant in the Basin; if this should occur, economic benefits derived from the iron ore would be increased. For purposes of this report, it has been assumed that if such a plant is built, transportation considerations will prohibit its location within the Basin.

The following assumptions have been made in arriving at the projected tonnage of iron ore production in Meramec Basin:

1. Gross National Product will continue to increase at least 3 percent a year.

2. Trade between U.S. and foreign countries supplying iron ore will not be restricted.

3. Reserves are sufficient to support contemplated production.

4. Demand in the year 2070 will be for blast furnace feed containing 60-70 percent iron.

Demand

It is estimated that domestic iron ore requirements in year 2000 will total about 215 million long tons of usable ore; the annual rate of growth would average about 2¼ percent increase per year. For purpose of this report, this rate was extended to the year 2070 where total domestic demand would approach 1 billion long tons. Iron ore in the Meramec Basin will satisfy 1 percent of the total demand. This estimate is based on discussions with individuals who know the industry and also on the characteristics of the industry itself.

In the near future, most of the demand for Missouri iron ore will come from eastern markets. However, as the demand for steel continues to move westward, so will the demand for iron ore. At this time, Missouri iron ore will have a distinct marketing advantage.[17/]

17/ Bethlehem Steel Corp., owner of half interest in Pea Ridge deposit, announced December 3, 1962, plans to construct a $250 million steel plant which will eventually be fully integrated. This plant is

being built to serve midwest steel markets and will be located in Porter County, Indiana.

Supply

Sufficient supplies of foreign and domestic iron ore are available to satisfy domestic demands in the foreseeable future. The major problems will stem from the various sources of supply competing for the consuming markets. The outlook for supply of iron ore is very fluid. Changing requirements by the steel industry have altered the required iron content of the ore until, in 1962, concentrates and/or ore should contain 60-65 percent iron.18/

18/ U.S. Bureau of Mines unpublished "Program Statement".

An assessment of the part which iron ore from Missouri will play in this aggregate picture is difficult because of lack of detailed information on reserves. Because of competition, many iron ore producers are reluctant to disclose data on reserves. It is assumed for this report that there are sufficient reserves to allow production in 2070.

Prices

The price of iron ore is negotiated between buyer and seller. As a base, the Lake Erie value is used with adjustments for physical and chemical characteristics of the ore. The effect of a price increase or decrease on the ore from the Meramec Basin is difficult to ascertain. Complications exist when the consumer of the ore is also the producer. As a generalization, any significant price increase would be of great

benefit to marginal producers; a price rise would enable the companies to sell ore at a profit and in the final analysis, this will determine level of production.

Transportation

Iron ore mined in the future in the Meramec Basin will be shipped by rail. If economics permit, ore will be transported by rail to the Mississippi River for trans-shipment by barge. Cost of transportation is one of the most important factors in determining how domestic demand is supplied. Since steel manufacturing is not a resource-orientated industry, raw materials, instead of finished or semifinished products, are transported the greatest distance.

Employment

Employment in 2070, based on 1960 annual output per man, should be approximately 3,000 workers in mining and beneficiating activities in the Basin's iron ore industry. One indirect result of the construction of the Meramec Park reservoir would be the possibility of employees moving closer to their work. Thus, it is possible that a small community could be built in the vicinity of the proposed lake and iron mine.

Pyrite and Marcasite

In the Meramec Basin, marcasite and pyrite are found in sink structures, usually beneath zones of oxidation which may have been mined in the past as a source of iron ore.

The last mining of pyrite and marcasite in Missouri occurred in 1940, with production of 29,325 long tons valued at $75,088. Prior to 1940, production from the Meramec Basin totaled 256,745 long tons valued at $793,088. Most of the ore was mined in Franklin, Crawford, and Phelps Counties.

Pyrite and marcasite were mined primarily as a source of sulfur for manufacturing sulfuric acid. Manufacturers who processed pyrite from Missouri mines are now purchasing the more economical elemental sulfur from Louisiana and Texas producers.

Data relative to the pyrite-marcasite reserves in Missouri are not available. The proposed reservoirs in the Meramec Basin will not have an adverse effect on pyrite-marcasite mining; none of the known deposits would be covered with water.

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Lead Deposits in Meramec River Basin

Geology

The geology of the area as related to lead, consists of a Precambrian basement of granites, rhyolites, and basic igneous rocks covered by a sedimentary succession of sandstones, dolomites, and interbedded shales. The Precambrian surface was formed by a long period of erosion and presented a relief of several hundred feet at the time of deposition of the Lamotte sandstone. The Bonneterre dolomites were subsequently deposited on the sandstone and provided the host rock for lead mineralization to follow. It is believed that the Precambrian granites and rhyolites were the source of the lead, zinc, and other metals that were transported by ground and surface waters to be concentrated in the dolomites. Lead mineralization generally is greatest in the lower portion of the Bonneterre formation and often occurs next to the Lamotte-Bonneterre contact. These are the mineralized horizons that have been and are being mined at the present time.

Topography of the mining district in the Basin is hilly to the west, with flat to undulating plains to the east, traversed by meandering streams.

The Lead Industry

The southeast Missouri "lead belt" lies within and adjacent to the Meramec Basin and has been the major source of domestic primary lead. Basin mine production, in terms of metal value, accounted for 30 percent of the domestic output in 1929, rose to 37 percent by

1943, then declined to a low of 22 percent in 1948 as Government assistance programs of price stabilization and national stockpiling brought in considerable marginal production (table 13). From 1950 to 1960, Basin output rose consistently with but slight cyclic variations from 27 percent in 1950 to a maximum of 42 percent in 1960 as new mine development in the Viburnum and Indian Creek areas exceeded declining production in the old "lead belt".

TABLE 12.- Lead production in short tons of recoverable metal in Missouri for selected years

Year	Prod. short tons	Value
Prior to 1800	18,000	$ 1,800,000
1800-1819	25,330	2,279,700
1820-1829	19,078	1,907,800
1830-1849	73,385	6,604,110
1850-1869	31,591	5,369,570
1870-1879	160,683	18,960,594
1880-1893	371,123	31,432,061
1900	58,582	5,187,103
1910	160,426	14,117,488
1920	165,037	26,405,920
1930	199,632	19,963,200

Source: Bishop, O. M. The Mineral Industry of Missouri in 1946-47, Division of Geological Survey and Water Resources, I.C. No. 4, 1949, p. 43.

Early records 19/ indicate production of 18,000 tons of lead metal from 1720 to 1800, rising to a total of 1.1 million tons from 1801 to 1900. By 1900, lead was being produced in counties other than those in the southeast lead belt, namely, the central and southwest Missouri districts.

19/ Winslow, Arthur. The Geology and Mineral Products of Missouri, from Missouri at the World's Fair, 1893.

TABLE 13.- Production and value of recoverable lead in select years, in Meramec River Basin, in Missouri, and in United States

Year	Meramec Basin Prod. Short tons	Meramec Basin Value	Missouri Prod. Short tons	Missouri Value	United States Prod. Short tons	United States Value
1929	197,430	$24,876,300	198,470	$25,007,100	650,320	$ 81,940,450
1940	159,610	15,961,100	172,050	17,205,200	457,390	45,739,200
1943	167,500	25,124,250	184,910	27,736,500	453,310	67,996,950
1948	85,380	30,567,100	104,030	36,619,100	390,480	139,790,400
1950	115,580	31,206,600	134,620	36,348,500	430,820	116,323,300
1951	106,340	36,793,300	123,700	42,800,900	388,160	134,304,750
1952	104,930	33,787,150	129,240	41,616,900	390,160	125,632,150
1953	107,000	28,034,000	125,900	32,984,500	342,600	89,772,750
1954	110,040	30,151,500	125,250	34,318,500	325,420	89,164,800
1955	114,770	34,202,850	125,410	37,372,800	338,020	100,731,450
1956	109,830	34,485,700	123,780	38,867,850	352,830	110,787,350
1957	112,780	32,255,650	126,340	36,134,650	338,220	96,729,800
1958	104,720	24,504,700	113,120	26,470,800	267,380	62,566,200
1959	101,140	23,262,200	105,160	24,187,950	255,570	58,780,650
1960	103,940	24,321,500	111,950	26,195,850	246,670	57,720,550
1961	98,160	20,213,350	98,790	20,349,700	261,920	53,956,000

Lead is one of a number of essential minerals that occur in the Meramec Basin and has the longest authenticated record of production; mining activity began before 1700. Lead minerals were being mined from outcrops by Chickasaw Indians who inhabited parts of the Basin when the earliest French explorers under Le Suer first learned of the occurrences. Early mining methods were very crude and consisted principally of open pits or shallow shafts on the outcrops. More systematic mining methods were introduced about 1880 with the advent of improved milling and smelting practices. Shafts were sunk to the bottom of the ore deposits and followed by regular mine development. The metal was used principally to make shot for firearms in the early dates, but as population increased and lead metallurgy improved, lead sheathing for roofing, pipes, and other industrial uses rose.

Mining Methods

Mineralization has been confined to relatively horizontal beds in the Bonneterre dolomites with irregular vertical extensions of considerable dimension. Mining is conducted in open stopes supported by random pillars. Present mining operations are largely mechanized, with drilling accomplished by 3-drill jumbos operated by two miners who also do their own loading and blasting. The broken ore is loaded with the famous "St. Joe" shovels into shuttle cars for transport to a 24-inch gauge underground rail system for movement to the ore-hoisting shafts. Ore at the newer operations of Indian Creek and Viburnum is hauled to the shafts in 10-ton trucks.

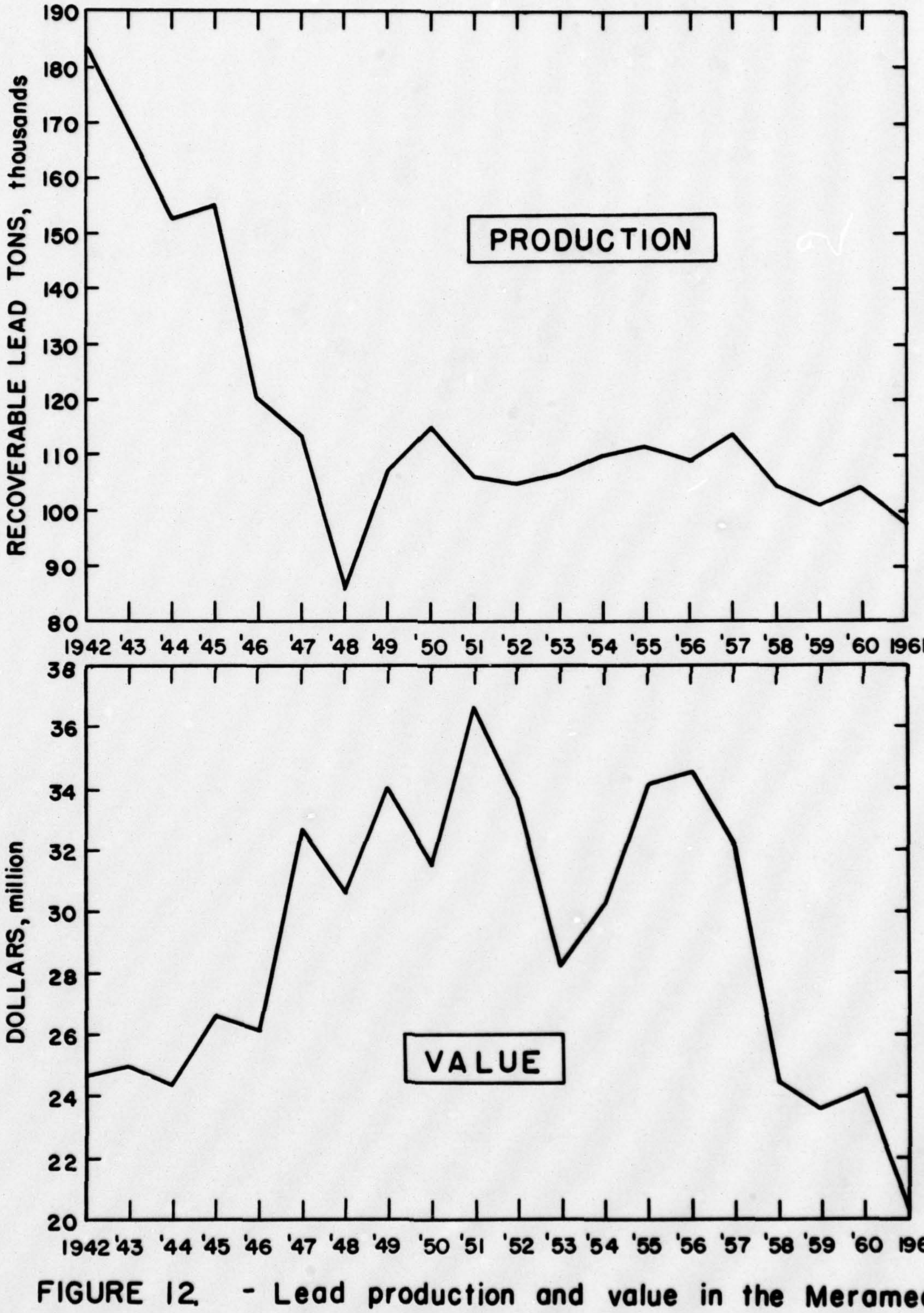

FIGURE 12. - Lead production and value in the Meramec River Basin, 1942-1961.

Milling Methods

There has been an average of six mills in the district for the past decade, with two new mills replacing two older mills since 1958. Each mill processes ore from two or more shafts. In the past, these mills combined gravity concentration (jigs and tables) with flotation; currently, all mills depend primarily on flotation recovery. Innovations and special equipment, developed by the St. Joseph Lead Co. and incorporated into mill processes, have improved operating efficiency and metallurgical recovery. Innovations include weightmeters installed on conveyors to record ore tonnages by source; units to control blend of ores and rate of feed from ore bins to ball mills; and several devices to weigh the circulating load, to measure pulp densities, and to control pulp densities of cyclone classifiers. All mills have grinding sections with primary crushers (cones), secondary crushers (rolls or cones), rod and/or ball mills, screens, elevators, classifiers, and storage bins. Concentration sections consist of flotation cells, pumps, reagent feeders, and accessory equipment.

Water Consumption

The lead mining, milling, and smelting industry water requirements in 1960 amounted to about 40 million gallons per day, most of the demand related to mining and milling. New water demands by the mining and milling sector amounted to but 15 percent, or about 6 million gallons per day, the difference having been met by reuse of impounded water, including additions pumped from underground mines. Except for special requirements, the 1 million gallons per day water

demands of the lead smelting industry were met from surface sources and returned to surface flows after a single pass.

Water conservation and anti-pollution practices of the lead mining and smelting industry have kept total water requirements at a minimum. Quality of water discharge meets specifications of State and Federal agencies.

Future Production Outlook

Reserves & Trends

Outlook for the lead industry in the Meramec Basin is favorable. The industry has developed sufficient reserves over the past several years to ensure its position as the Nation's major source of lead. Reserves are estimated to be over 10 million tons of recoverable lead. The local industry has an enviable transportation position with adequate rail, barge, and truck facilities available to the Midwest, Great Lakes, and the Ohio River industrial complexes.

It appears inevitable that another lead smelter requiring large capital investment, generating important increases in labor, income, services, and requiring more homes will be built in or near the Basin. A factor contributing to this premise is the large number of mineral holdings by large mining companies with subsequent large lead reserves that must be developed.

New large lead deposits have been discovered near Viburnum in Iron, Crawford, and Washington Counties by St. Joseph Lead Co. and a number of other major mining companies, and at Oates, in Iron and Dent

Counties (fig. 13). St. Joseph Lead Co. is producing from developments in Iron and Crawford Counties and expects to complete a third producing shaft in Washington County in 1963. Other major mining companies tentatively plan to develop their holdings within the next several years and will require new lead milling, smelting, and refining capacity to process the new mine production. The new facilities will undoubtedly be built in or near the Basin for economic reasons.

A few major mining companies have always been responsible for most of the production in the district. Factors contributing to large rather than small operations were: large land grants to the early settlers under French and Spanish rule; wide dissemination of ore and the moderate grade of enrichment; and vertical integration of most early operations from mining through milling and smelting.

Economics of Lead Mining and Smelting Industry

The lead mining and smelting industry of the Meramec Basin (including areas contiguous to or near the Basin) is an important and integral part of an international industry. In fact, in terms of the aggregate domestic industry, it is the most significant lead-producing area. As a result, economic analysis of this commodity must consider factors of the total industry and cannot be limited to narrow confines of the Meramec Basin. However, it was impossible to develop this type of analysis within the time limit imposed on this report. Consequently, in this report, some salient features of diverse economic factors are presented in order to indicate the future of this industry in Missouri.

Supply

The lead mining industry of the Meramec Basin is the Nation's major domestic supplier of lead ores (table 14). In 1960, Basin mine production was responsible for 42 percent of U.S. output and 17 percent of total U.S. supply. Table 14 indicates the importance of this area to the overall domestic lead industry. Even though lead produced from Meramec Basin is becoming less important to total supply, its prominence in regard to the Nation's domestic production is increasing. From 1929-60, Basin lead mine production declined at an annual rate of 3.1 percent. Basin lead production accounted for 31 percent of domestic lead production in 1929 and 42 percent in 1960. During this period, the domestic industry's share of total supply (includes imports) had dwindled from 85 percent to 40 percent. Imports over the past decades have affected the traditional patterns of supply. Lead ores shipped from Union of South Africa, Peru, Canada, and Australia, and lead metal supplied by Mexico, Australia, Yugoslavia, Canada, and Peru accounted for 60 percent of total U.S. supply in 1960.

TABLE 14.- Salient data on supply and output of lead for selected years

	1929	1940	1945	1950	1955	1960
Meramec production as percent of total U.S. supply	31	35	40	27	34	42
Meramec production as percent of total U.S. supply	27	22	22	12	14	17
Net imports as percent of total U.S. supply	15	22	44	56	51	60

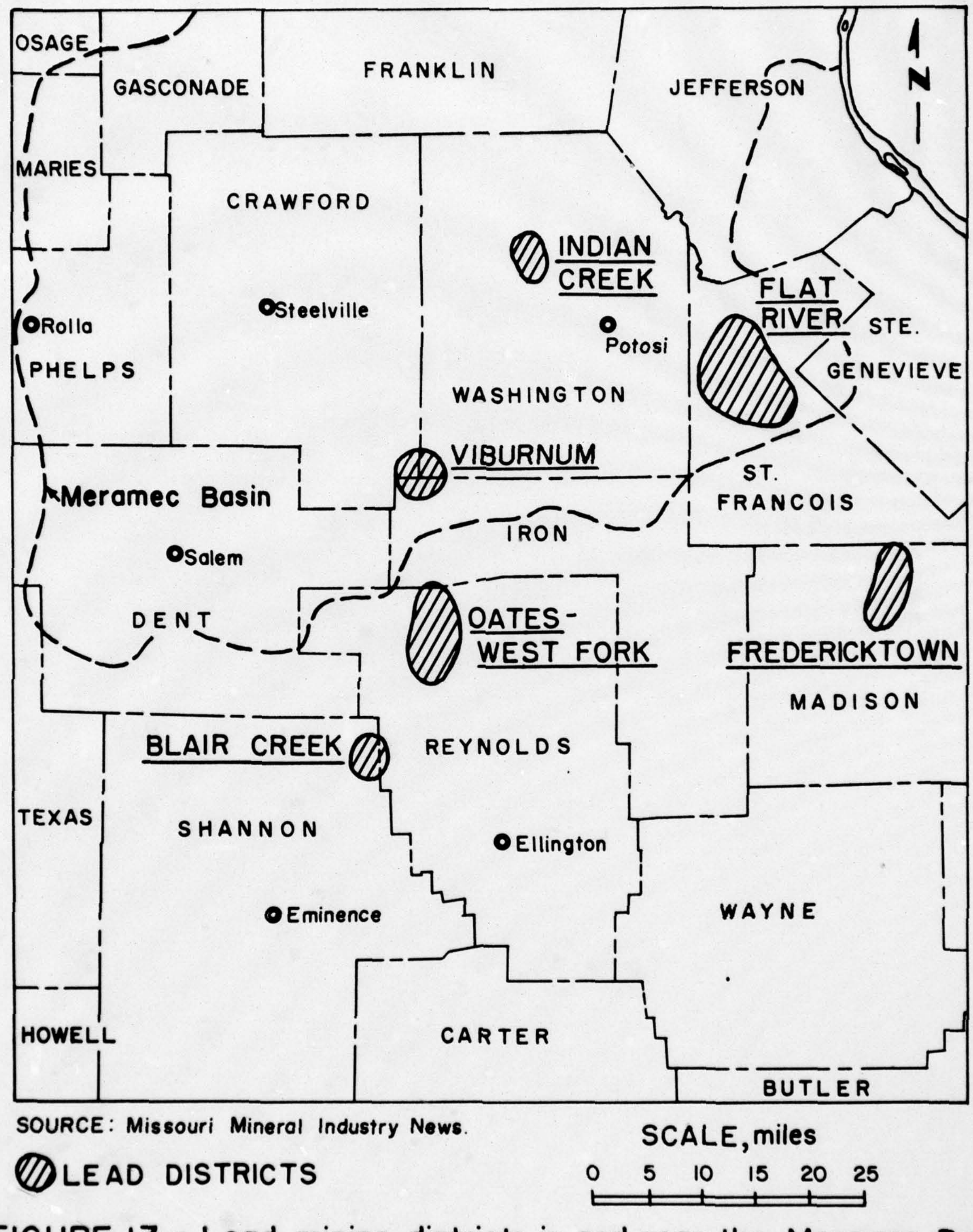

FIGURE 13. - Lead mining districts in and near the Meramec Basin, Missouri.

It is expected that because of mineral deposits amenable to mechanized operation, available lead smelting and refining facilities, adequate labor, water, and transportation facilities, the local industry will maintain its position as a major domestic supplier of lead.

Demand

For purposes of this report, consumption of primary and secondary lead as reported by the Bureau of Mines in the Minerals Yearbook will be used as the measure of demand. Consumption of lead in 1960 was almost the same as that in 1929. Over this same period, national output as measured by Real Gross National Product increased almost 1½ times. Thus, consumption of lead lagged significantly behind the trend of national output.

The use pattern of lead has remained stable for the past several years; new and substantial markets have not been discovered. The lack of new uses for lead, coupled with competition from other products, has resulted in a static demand over the past two decades.

The demand for lead in the United States in the year 2000 should be approximately 1.5 million tons. This estimate was calculated by extrapolating the trend of lead consumption from 1940 to 1960.

Prices

Lead prices in St. Louis declined from an average of 15.81 cents in 1956 to 11.75 cents in 1960, a reduction of 26 percent. Much of the difficulty results from increasing foreign competition for declining markets.

Relation to Economy of Meramec Basin

The local lead mining and smelting industry is a substantial contributor to the economic life of the Meramec Basin, as shown in table 15.

TABLE 15.- Lead mining - Missouri

	1954	1958	1960
No. of employees	3,451	2,852	2,331
Payroll ($000)	13,731	12,256	10,517
Average wages per employee	3,979	4,297	4,512
Value added in mining ($000)	22,709	17,727	17,451
Cost of supplies, etc. ($000)	5,189	8,031	8,212
Capital expenditures ($000)	775	2,375	2,350
Value of shipments ($000)	30,563	23,381	23,138

Source: Census of Mineral Industries, Department of Commerce

Though most of the items in the table have shown a drop in each Census year enumerated, their contribution to the Basin's economy remains significant because of their magnitude. The 30 percent decline in mine employment from 1954 to 1960 is a result of improved technology through mechanization in order for the Basin industry to maintain its competitive position in periods of declining markets for domestic ores. In this period, the Basin lead industry generated wages estimated at $10.5 million in 1960, a most significant addition to the Basin economy. Average annual wages of industry employees rose 13 percent to $4,512.

The declines in value added in mining and value of shipments are indicative of the economic instability that has plagued the domestic industry for years. The rise in supply costs and capital expenditures in the 1954-60 period largely represents the transfer of a major part of Basin industry activity to the newly developed Viburnum area.

The Herculaneum smelter of St. Joseph Lead Co. in Jefferson County has an annual rated capacity of 100,000 tons of metal, representing 11 percent of total domestic capacity. Employment in 1960 was approximately 500 workers who lived within a 20-mile radius of the plant. Wages amounted to $2.2 million. The Basin economy is benefited to some degree by the wages paid and the supplies and services required by the smelting operation. Recent changes in the domestic lead smelting and refining industry (abandonment of 320,000 tons of smelting capacity, much of which processed midcontinent lead ores) tender an interesting problem on where a significant tonnage of future lead mine production not committed to installed smelter capacity will be processed. There is a complete lack of a lead market for midcontinent ores through absence of lead smelting capacity for custom ores. This situation developed when the East Alton, Ill., and Leadville, Colo., lead smelters of American Smelting & Refining Co. were abandoned and The Eagle-Picher Co. drastically curtailed pigment production at its Galena, Kans., operation.

Projections

The following assumptions were made in determining future production and employment in the lead industry of the Meramec Basin as it has been defined in this report.

1. The relationships between primary and secondary lead supplies will not change.

2. The domestic industry will maintain its 1960 share of at least 40 percent of the total U.S. demand.

Though the Basin lead mining industry output declined 2.1 percent in the period 1929-60, recent discoveries in and adjoining the Basin should permit the industry to improve its share of the domestic market within the next decade. The degree and timing of this improvement will be determined by:

1. The extent to which mining companies, other than St. Joseph Lead Co., holding large leases and lead reserves in the Viburnum and other explored areas, will develop these properties.

2. The extent to which these same companies substitute this new production for established production from other areas. It is doubtful that their current output will be supplemented until economic factors are favorable.

3. The size and location of a custom concentrator, lead smelter, and refinery to process this new ore.

4. The degree of the industry's continued success in exploration projects near the Basin.

5. Status of world and domestic markets, including discovery or development of new uses.

It is anticipated that the Basin lead mining industry will provide about 160,000 tons of recoverable lead in 1970, an annual increase of 4.8 percent. About this time, Basin output should level off and increase at an annual rate of 0.7 percent to the year 2000 when 220,000 tons will be produced. The lead deposits, as we now know them, could

be depleted by the year 2020. Thus, in the year 2000, Basin output will supply about 15 percent of the estimated demand of 1.5 million tons of lead. It has been assumed that new and significant uses of lead will not be developed.

During this period of time, there will be a shift in labor force and population associated with the lead industry. As the Viburnum and Oates areas are developed and production in the lead belt is phased out, there will be a movement of personnel from the latter to the newer areas. It must be pointed out that, because of greater mechanization of the newer mines and higher grade ore, employment in these mines will not be sufficient to absorb all of the displaced employees from the lead belt.

Other Metals Associated with Lead

A number of metals such as zinc, copper, silver, cobalt, nickel, and cadmium are associated with lead minerals and are recovered by the lead industry in the Meramec Basin. Their production is so dependent upon the experiences of the lead industry that normal analysis, based on demand and other economic factors, is precluded. District production from earliest records to 1961 amounted to approximately 35,000 tons of copper, 90,000 tons of zinc, 7 million fine ounces of silver, 7 million pounds of cobalt, and 10 million pounds of nickel.

With the exception of silver, the lesser metallic minerals enumerated above occur principally as sulfides, with galena the dominant lead mineral. Cobalt and nickel occur as the mineral siegenite, usually associated with copper and iron. Significant Co-Ni concentrations have been found; earliest production was reported in the early 1840's when these complex ores were treated at a small furnace near Fredericktown. Desultory production has occurred since, with operations largely dependent upon variable markets for cobalt or nickel. After World War II, production was influenced by requirements of Federal defense agencies and stockpile programs, with St. Louis Smelting & Refining Division of National Lead Co. operating the Government-owned refinery at Fredericktown. This refinery was shut down in the first quarter of 1961 and is now being dismantled.

Both cobalt and nickel are used primarily as an alloy in steel; as a result, demand follows that for steel. Other important uses for cobalt include additives to porcelains and glass and as a catalyst in ammonia manufacture.

Copper production was first reported from Shannon County (outside the Meramec Basin) about 1837, with 1,500 tons of smelting ore mined during the period 1837-41. Copper minerals in combination with cobalt, nickel, iron, and lead were produced at Mine La Motte and near Fredericktown from 1870 to about 1910. Copper concentrates, along with cobalt, nickel, and lead, were produced at Fredericktown since World War II by the St. Louis Smelting & Refining Division of National Lead Co. Copper mineralization occurs to a minor extent with most lead ores in and about the Basin area and continues to be recovered as a

byproduct. Copper markets are as extensive and widely distributed as those of lead. Major uses of copper include: electrical apparatus and controls, building, communications, railroads, ammunition, alloys of bronze and brass, and compounds of the chemical industry.

Zinc minerals are intimately associated with lead minerals, but technology and markets delayed their recovery to about 1860. At that time, Matthiessen & Hegler Zinc Co. built a smelter at La Salle, Ill., to provide a market for midcontinent ores; a small zinc smelter was built at Potosi in the Meramec Basin in 1867. Zinc, like copper and lead, has many uses, the principal ones being galvanizing, die-casting, combining with copper to make brass and bronze, and as paint pigment.

Silver occurs intimately with the lead ores of the southeast district and is recovered in refining of the lead bullion to make "soft" or chemical lead. Most lead ores in the Basin contain 1 or 2 ounces of silver to each ton of lead concentrate; annual recovery averaged 50,000 to 100,000 ounces, depending on the demand for refined lead. Future silver recovery from Missouri lead ores should increase as industrial markets become available with the termination of Government regulations of newly mined silver. Silver recovery should approximate 300,000 to 500,000 ounces annually if silver demand and price warrant refining most of the lead from Missouri concentrates. Monetary demands consume most of the silver, with jewelry and photographic chemicals requiring significant quantities.

Future production of these metals - copper, zinc, cobalt, nickel, and silver - will be largely governed by the Basin's lead-producing industry since they cannot be produced individually. Under these circumstances, the outlook for these metals will be that reported in the lead section.

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Sand and Gravel in Meramec River Basin

Introduction

Commercial sand and gravel is produced in Franklin, Jefferson, Ste. Genevieve, St. Louis, and Washington Counties. Of these, only Washington County can be considered completely within the Meramec Basin. In addition to State and Federal highways, transportation facilities are supplied by Missouri Pacific Railroad, Missouri Illinois Railroad, St. Louis-San Francisco Railroad, and Chicago, Rock Island & Pacific Railroad. Each railroad services at least two of the Meramec Basin counties which have commercial sand and gravel output. Principal streams include the Bourbeuse, Meramec, and Big Rivers and Little Piney Creek in Phelps County. Ultra-pure silica sand is produced in Jefferson and St. Louis Counties; current output in Jefferson County is outside the Meramec Basin (fig. 14). Deposits of silica sand sufficiently pure to be used in glass manufacturing and chemical industries are limited. Thus, the silica deposits in the Meramec Basin comprise one of the Nation's significant sources and reserves of high-quality material.

Geology

Except for silica sand, sand and gravel in the Meramec River Basin counties is produced mainly from stream or fluvial deposits in the Bourbeuse, Meramec, and Big Rivers and Little Piney Creek. The chief gravel-producing streams in the Meramec Basin counties are Meramec River and Little Piney Creek. Meramec River sand and

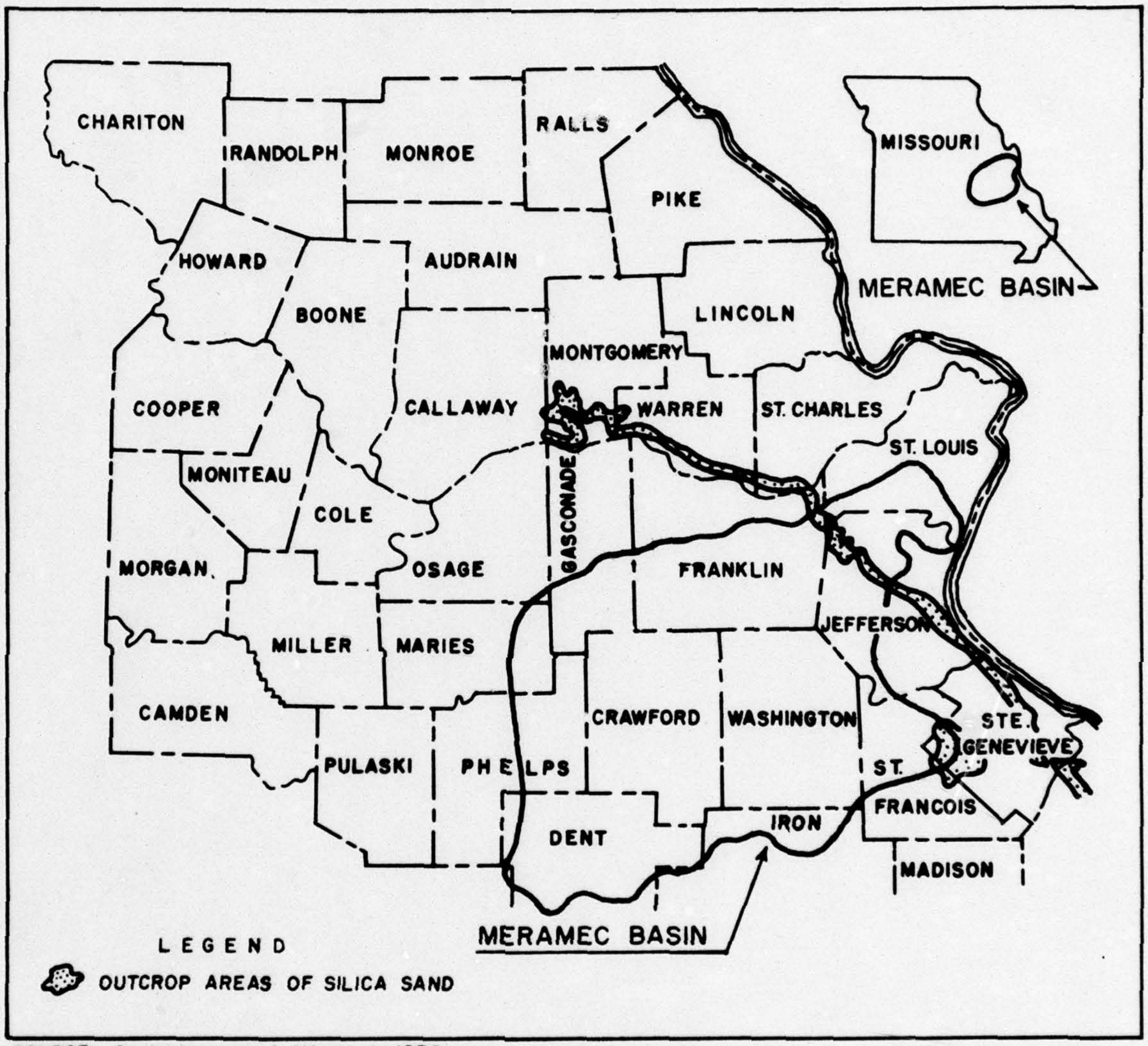
gravel consists entirely of subangular to sharp particles of flint and quartz. Sand and gravel from Little Piney Creek consists of chert and quartz.

Silica sand is produced from St. Peter and Everton formations, which, in Meramec River Basin counties, begin in southeast Ste. Genevieve County and extend northwest, cross into Jefferson County about two miles west of the Mississippi River, and then parallel the river to Crystal City. From Crystal City, the formations turn westerly, pass through the southwest corner of St. Louis County and the northeast corner of Franklin County at Pacific, and cross the Missouri River at Klondike. The St. Peter sandstone belt is overlain by the Joachim, a moderately thin-bedded dolomite or dolomitic limestone. From the vicinity of Crystal City south, the St. Peter rests on the Everton formation. Throughout the belt, the St. Peter sandstone proper averages about 80 feet in thickness and has a moderate northeasterly dip; its most evident topographic characteristic is a prominent escarpment.

The Sand and Gravel Industry

Commercial Production

In 1961, 28 of the State's 78 commercial sand and gravel operations were located in the Meramec River Basin counties (table 16 and fig. 15). Sand and gravel output in the Meramec Basin in 1961 totaled 5 million tons valued at $6.3 million, 58 percent of the total State tonnage and 62 percent of total State value. Silica sand production, included in the total sand and gravel data, totaled 488,000 tons valued at $1,867,000.



SOURCE : Geologic map of Missouri - 1939

FIGURE 14. - Silica sand resources in the Meramec Basin, Missouri.

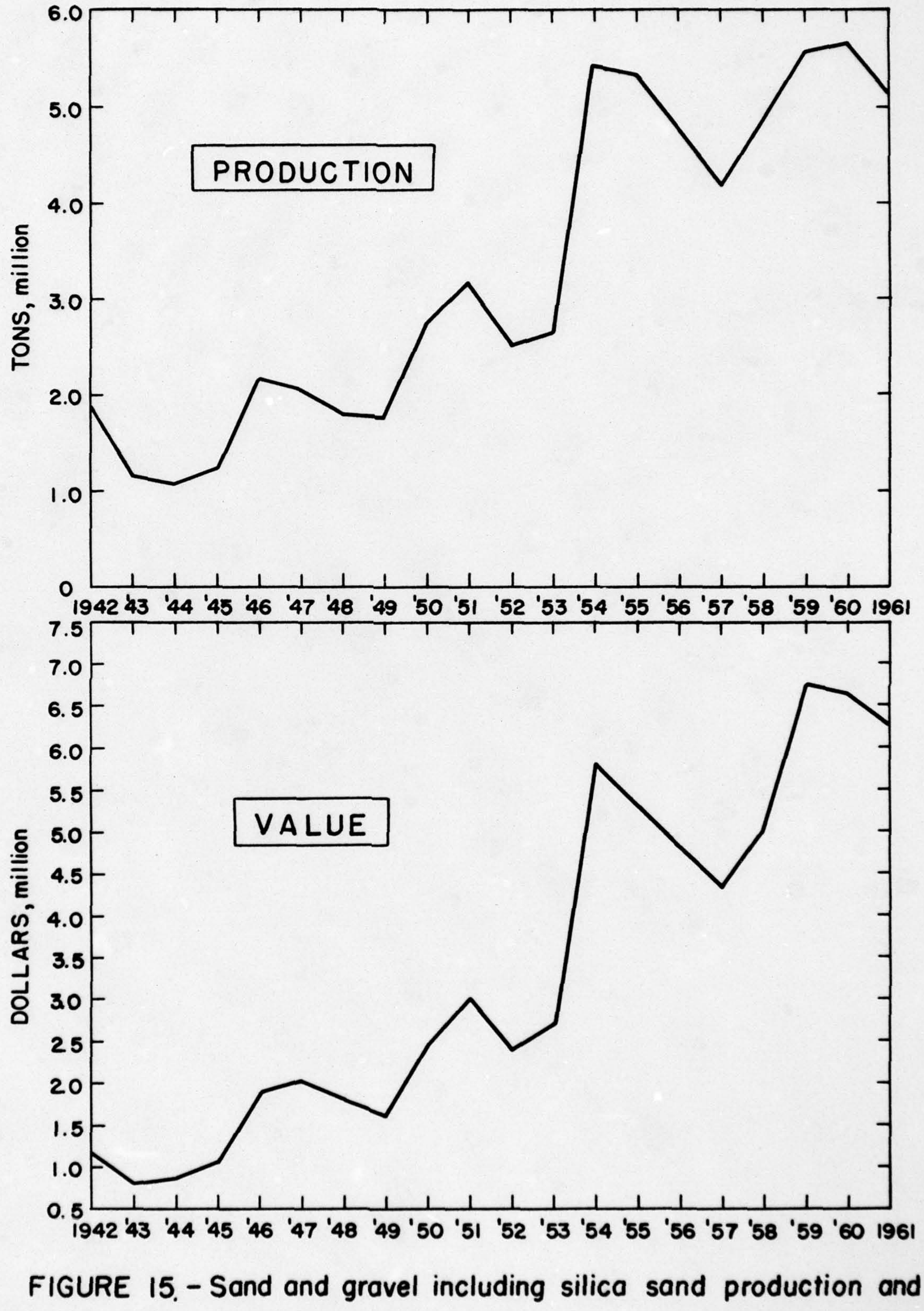


FIGURE 15. - Sand and gravel including silica sand production and value in the Meramec River Basin, 1942-1961.

Sand and gravel produced from streams is used mainly for construction purposes; other uses include railroad ballast, fill, grinding and polishing, blast sand, and engine sand. The silica sand is used principally in glass manufacture.

TABLE 16.- Commercial sand and gravel production in Meramec River Basin counties

Year	Total sand and gravel including silica sand: Short tons	Total sand and gravel including silica sand: Value	Silica sand: Short tons	Silica sand: Value
1942	1,935,220	$1,165,616	95,873	$ 140,595
1943	1,195,134	794,177	109,144	174,102
1944	1,105,255	843,411	214,033	321,250
1945	1,241,315	1,090,567	212,651	330,424
1946	2,247,951	1,897,475	299,399	480,069
1947	2,049,297	2,004,968	397,293	605,480
1948	1,813,862	1,786,175	331,921	534,665
1949	1,834,962	1,586,271	264,445	473,397
1950	2,646,350	2,475,546	349,372	649,676
1951	3,161,005	3,025,215	476,918	898,219
1952	2,480,529	2,376,001	459,048	907,747
1953	2,701,355	2,702,106	475,985	941,532
1954	5,496,922	5,805,183	480,365	1,114,397
1955	5,261,947	5,330,061	535,698	932,822
1956	4,756,884	4,897,272	478,115	1,007,691
1957	4,201,986	4,303,181	462,877	988,335
1958	4,846,550	4,988,637	385,782	947,637
1959	5,542,938	6,815,919	552,612	1,902,762
1960	5,616,172	6,664,167	547,846	1,817,661
1961	5,047,989	6,342,446	487,514	1,867,035

The average price of commercial sand and gravel produced in the Meramec Basin in 1961 was $1.26 per short ton, f.o.b. plant, compared with the State average of $1.17 per ton. The higher unit value for the Meramec Basin output is due mainly to inclusion of silica sand, which had a unit price of $3.83 per ton in 1961.

Mining and Beneficiation

Methods of recovering sand and gravel from streams vary considerably, depending on size and permanence of the operation. Suction type dredges and draglines are the two principal methods employed. At a typical Meramec operation, the material is processed in a plant on the bank of the stream. Twenty six of the 28 commercial operations in the Meramec Basin counties in 1961 were stationary plants and 2 were portable plants.

Silica sand is produced by four companies in the Basin counties, three by open quarry methods (one in St. Louis County and two in Jefferson County) and one by underground room-and-pillar methods (Jefferson County).

Water Consumption

Operators producing sand and gravel from streams use water from the stream to wash the material; the water, carrying fine silt and clay, is usually returned to the stream. Sources of water consumed by silica sand operations are: (1) ground water and, (2) stream or river. Operations using ground water discharge used water to surface flow or to settling ponds. About 90 percent of the water taken from streams is returned to stream flow. A common formula for water usage in the sand and gravel industry is 400 gallons per ton. Using this formula, the amount of water used in preparing sand and gravel in the Meramec River Basin counties in 1961 was about 2 billion gallons; about 1.8 billion gallons was returned to the stream.

Future Production Outlook

Market Trends

The principal market area for Meramec Basin producers of construction sand and gravel is the St. Louis metropolitan area. Demand for sand and gravel will continue in line with new construction activity. New construction in the Nation is expected to double from 1960-1975, and double again from 1975-2000, according to the Business & Defense Services Administration, U.S. Department of Commerce.

The principal uses for silica sand, in order of magnitude, are for glass, grinding and polishing, molding, and abrasives (ground sand). Demand for silica sand should continue to grow with the growth of the national economy.

Economics of Sand and Gravel Industry

Sand and gravel from the Meramec River Basin is principally used as concrete aggregate. Because sand and gravel is a large-volume, low-unit cost item, transportation costs limit the distance from the producing operation to the market area. Proximity to metropolitan areas is an important factor in determining economic feasibility of a sand and gravel operation.

The principal use of silica sand is in manufacturing glass. Markets for silica sand produced in Meramec Basin counties include the manufacture of automotive glass in Jefferson County and glass plants in eastern States. Silica sand for molding, grinding, polishing, and other uses goes to various markets in the United States.

The sand and gravel industry in Meramec Basin counties provided employment for over 400 employees in 1960, with a total payroll of approximately $1.8 million. The average annual wage per employee was about $4,100, based on a 5 percent increase over the average wage compiled by the 1958 Census of Mineral Industries. Value added in mining sand and gravel in the Meramec Basin in 1960 was an estimated $4.4 million. Value of commercial sand and gravel sold or used in the Meramec Basin counties in 1961 was $6.3 million, approximately 60 percent of the State's total commercial output.

The outlook for sand and gravel production appears satisfactory, based on projections of construction activity. However, construction of dams on the various streams in the Meramec Basin will affect future sand and gravel output by restricting the natural replenishing of sand deposits by stream flow. Sand and gravel available from the Mississippi and Missouri Rivers will be adequate to supply requirements to 2070.

Assuming continuation of the growth in construction activity and the national economy, the projected 2070 demand for silica sand and sand and gravel (commercial) from the Meramec Basin counties is 34.5 million tons. On the basis of 1960 production rates, Meramec Basin employment required for the 2070 demand will total approximately 2,600. Sand and gravel production, in general, is scattered along the streams, and assignment of employees to specific geographical areas is not feasible.

Applying the common water-use formula of 400 gallons per ton of sand and gravel processed, a total of 13.8 billion gallons will be used in 2070. Assuming a processing loss of 10 percent, approximately 12.4 billion gallons will be returned to stream flow carrying quantities of fine silt and clay.

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Stone in Meramec River Basin

Granite

Geology

Numerous surface exposures of Precambrian rhyolites and granites are found in the south portion of the Meramec River Basin. These generally are on the highlands; their resistance to erosion has created the rounded hill topography of the area. The rhyolites are dark red, brown, or black and are fine textured with small imbedded phenocrysts of quartz or feldspar. Rhyolites have not been popular as building or monumental stone. The granites are composed chiefly of orthoclase and quartz with minor amounts of hornblende and biotite. Generally of a rather pleasing reddish color, the granites take a high polish and are in demand for building and monumental stone. Diabase dikes, from a fraction of an inch to six feet in width, have intruded into both the granites and rhyolites.

The Granite Industry

History.-The first granite quarry in the area was opened in 1869 near Graniteville, Iron County, Mo., and the product was used for building construction. Many of the more elaborate, early-day structures, especially in St. Louis, were built with this stone. In 1877, granite blocks were used in street paving in St. Louis, and in the following years many quarries were opened to supply paving blocks and curbstones. Since the early 1900's, use of concrete and other materials for paving and changes in large building construction methods have limited the uses of Missouri granites to facing and ornamental stone for large structures.

Current Production.-There is presently one operation employing 41 men in the Graniteville area at the south edge of the Meramec River Basin. Missouri granite production, tonnage, and value for the period 1894 to 1961 is shown in table 17. The same information is shown in graphic form in figure 16. Value of the product depends upon the extent to which the stone is finished. In 1961, dimension stone used in construction, rough, and dressed monumental sold at an average price of $11.10 per ton. Waste and broken granite used for riprap and crushed stone brought $2.05 per ton.

TABLE 17.- Missouri production of granite, 1894-1961

Year	Tons	Value
1894-1947 1/	532,270	$5,378,845
1948	5,790	130,609
1949	6,910	176,902
1950	4,490	161,935
1951	6,972	168,607
1952 2/	11,618	149,196
1953	5,882	164,792
1954	3,827	169,935
1955	2,821	179,483
1956	3,456	301,857
1957	5,369	231,623
1958	3,648	259,663
1959	3,111	275,711
1960	3,806	233,341
1961	4,532	295,137

1/ The Mineral Industry in Missouri. Missouri Geological Survey and Water Resources. I.C. No. 4.

2/ High tonnage and low value due to large amount used for riprap.

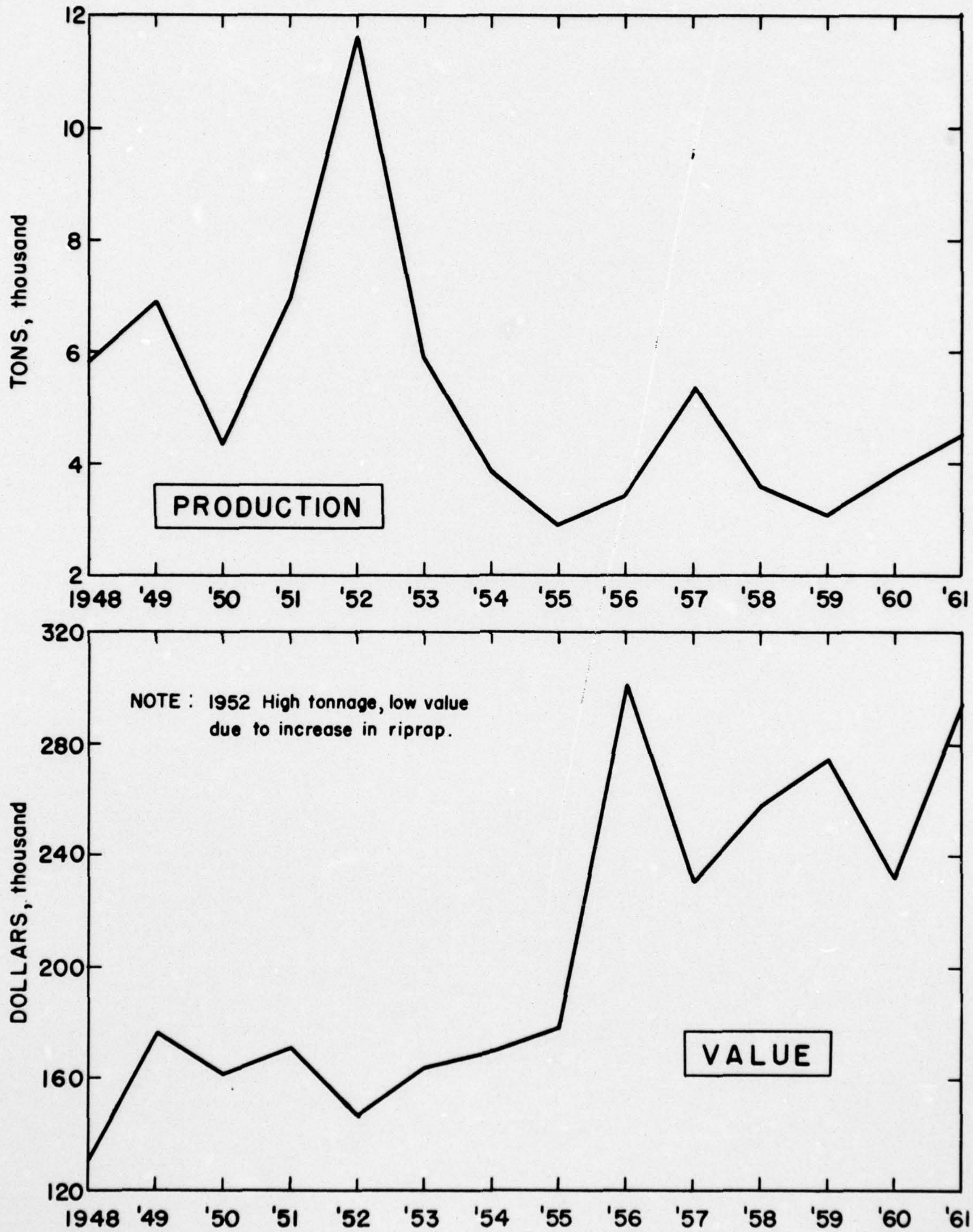

FIGURE 16.-Granite production and value in Missouri, 1948-1961.

The major portion of the Missouri granite production is used for rough and finished monumental stone. Limestone and granites are used exclusively for this trade and severe competition from substitute materials is unlikely. A large percentage of the Missouri granite is shipped to new England finishing plants where it is used as a contrast color stone for the gray granites produced in that area. Byproducts of the quarry operations are riprap stone and crushed granite, which utilize some of the waste and breakage.

Mining Methods.- The granite deposits are massive with a regular system of major and minor joints which, in some cases, are perpendicular to each other. There is some slight horizontal bedding which aids in quarrying large blocks. Both features are so irregular that large-scale planning is difficult. The method of quarrying is to secure blocks of the desired size by "plug and feather" methods. Advantage is taken of the natural joints in the stone where possible. A line of shallow holes is drilled along the break line with pneumatic machines or by jet piercing. An even pressure is exerted along the whole line with steel wedges and hand sledges to prevent a cross break. The blocks are lifted out with derricks and taken to the finishing plant or loaded onto railroad cars for shipment. The company maintains a three-mile spur connecting the plant with the main line of the Missouri Pacific Railroad.

Water Usage.- Rainfall, collected in three small, shallow ponds, furnishes water for use at the one granite quarry in the Meramec Basin; an emergency supply is available from a nearby stream. An estimated 2,000 gallons per day is circulated through the finishing plant, with a loss of approximately 10 percent. Virtually no water is used in the quarrying operation. No water is released into the drainage system.

Future Production Outlook

Reserves.-An abundance of granite is known in the area; reserves are practically unlimited at present scale of production.

Economic Trends.-Future production of granite will increase only slightly during the coming years as it is dependent on use as monumental stone. New uses would have to be developed to change the situation and this appears unlikely at the present. Prices will also have a tendency to rise slightly because large-scale economical production methods are not applicable.

Limestone

Geology

Sedimentary rock outcrops in the Meramec River Basin range in age from Ordovician to Pennsylvanian and are predominately dolomites and limestones. Principal outcrops in the western and central parts of the Basin are dolomites which, though inferior to the high-calcium limestones in the eastern part of the Basin, are used locally for road-stone and agricultural lime. The Jefferson City formation of Ordovician age is the producing stratum in Phelps, Franklin, Crawford, and Dent Counties. In the eastern part of the Basin, limestones of Mississippian

age are exposed; the St. Louis, Spergen, and Burlington formations are extensively quarried. These are high-calcium limestones, and the products are suitable for concrete aggregate, roadstone, agricultural limestone, and lime and cement manufacture. Cambrian dolomites outcrop in the southern part of the Basin and are quarried for refractory and chemical uses.

The Limestone Industry

History.-Pioneer white settlers were the first producers of limestone and dolomite in the Meramec River Basin; the stone was used as rough building blocks or burned to quicklime to make mortar. As the area developed, a more finished stone of uniform grade and color was wanted, and structural and monumental shapes were cut and finished at the quarry. The first crushed limestone was used on construction of Macadam roads. When cement came into general use at the beginning of the century, limestone was required for use in its manufacture and demand increased for a crushed and sized aggregate for concrete mixtures. During the period 1952-61, pavement and concrete structures required the largest amounts of limestone and utilized 30.3 percent of the production in the Meramec River Basin. Cement and lime manufacturing were next, with 22 and 29 percent, respectively. During the 1920's, the worth of finely crushed limestone as a soil conditioner became well established and use for this purpose expanded rapidly. This development enabled quarries to utilize fines produced in crushing operations; 7 percent of the limestone produced in the Meramec River Basin is currently used as soil conditioner.

Current Production.-Production and value figures for a 10-year period, 1952-1961, as shown in table 18, are compiled from the 39 producers in and near the Meramec River reporting to the U.S. Bureau of Mines.

TABLE 18.- Limestone production in Meramec River Basin (1952-1961)

Year	Production (short tons)	Value
1952	5,414,226	$ 8,002,210
1953	6,196,925	8,291,203
1954	6,315,580	8,646,850
1955	6,542,062	9,704,892
1956	7,234,249	11,008,160
1957	6,848,788	9,218,272
1958	7,357,459	9,933,073
1959	8,532,512	10,846,880
1960	8,123,087	10,325,463
1961	8,681,397	11,085,436

The figures include production and value of tailings sold from lead concentrating mills at which the gangue is predominately dolomite. These data are presented in graphic form by the curves on figure 17.

Crushed limestone production in the Meramec River Basin area in 1960 was 29.2 percent of Missouri production and 1.7 percent of total U.S. production. The larger operations are in the eastern portion of the Basin where the rock has a higher calcium content and is nearer to larger markets. Cement and lime plants are located in these areas. In the western portion of the Basin, the operations are generally smaller and are often worked with portable equipment which is moved from one location to another. Limestone production and value from the 11 counties comprising the Meramec River Basin are given in table 19.

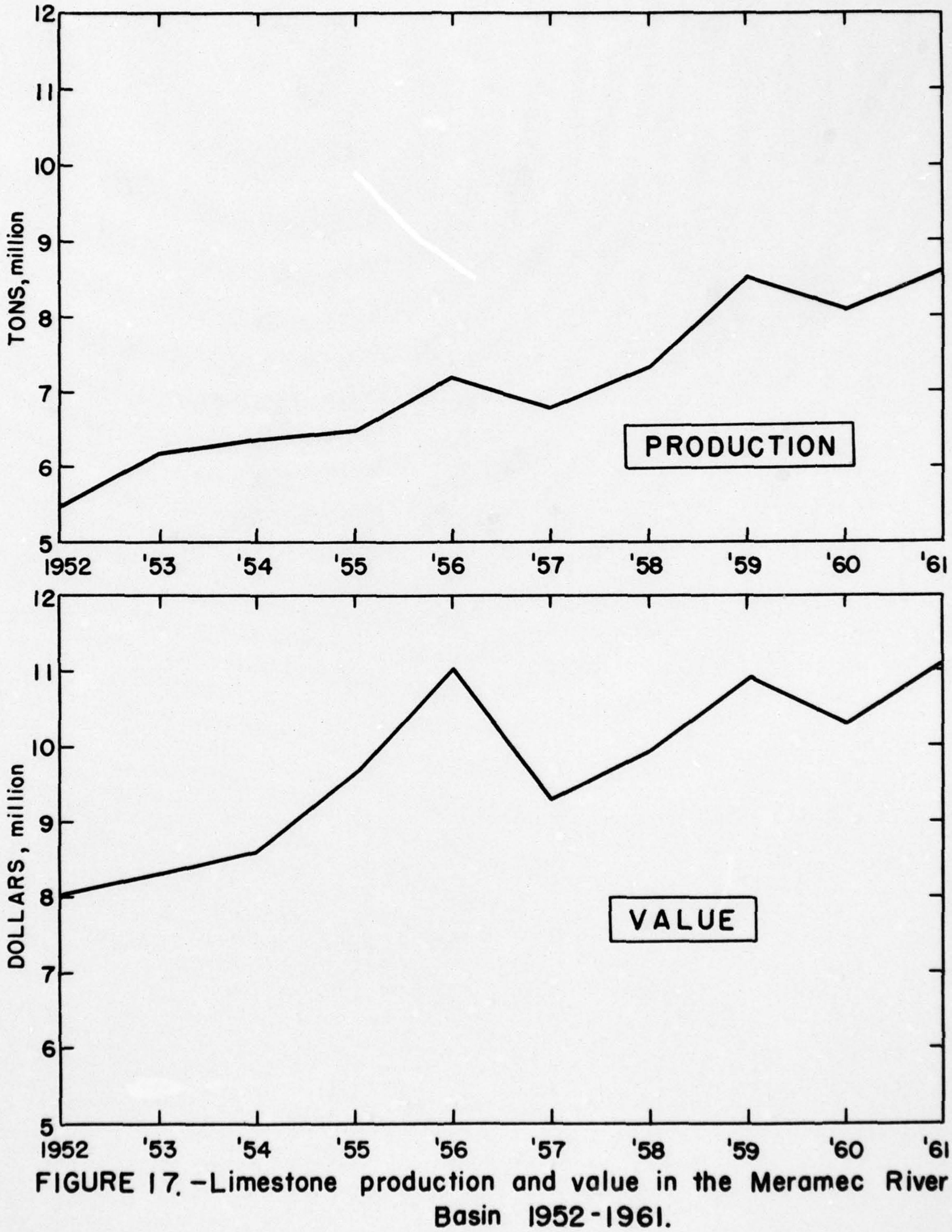

FIGURE 17. -Limestone production and value in the Meramec River Basin 1952-1961.

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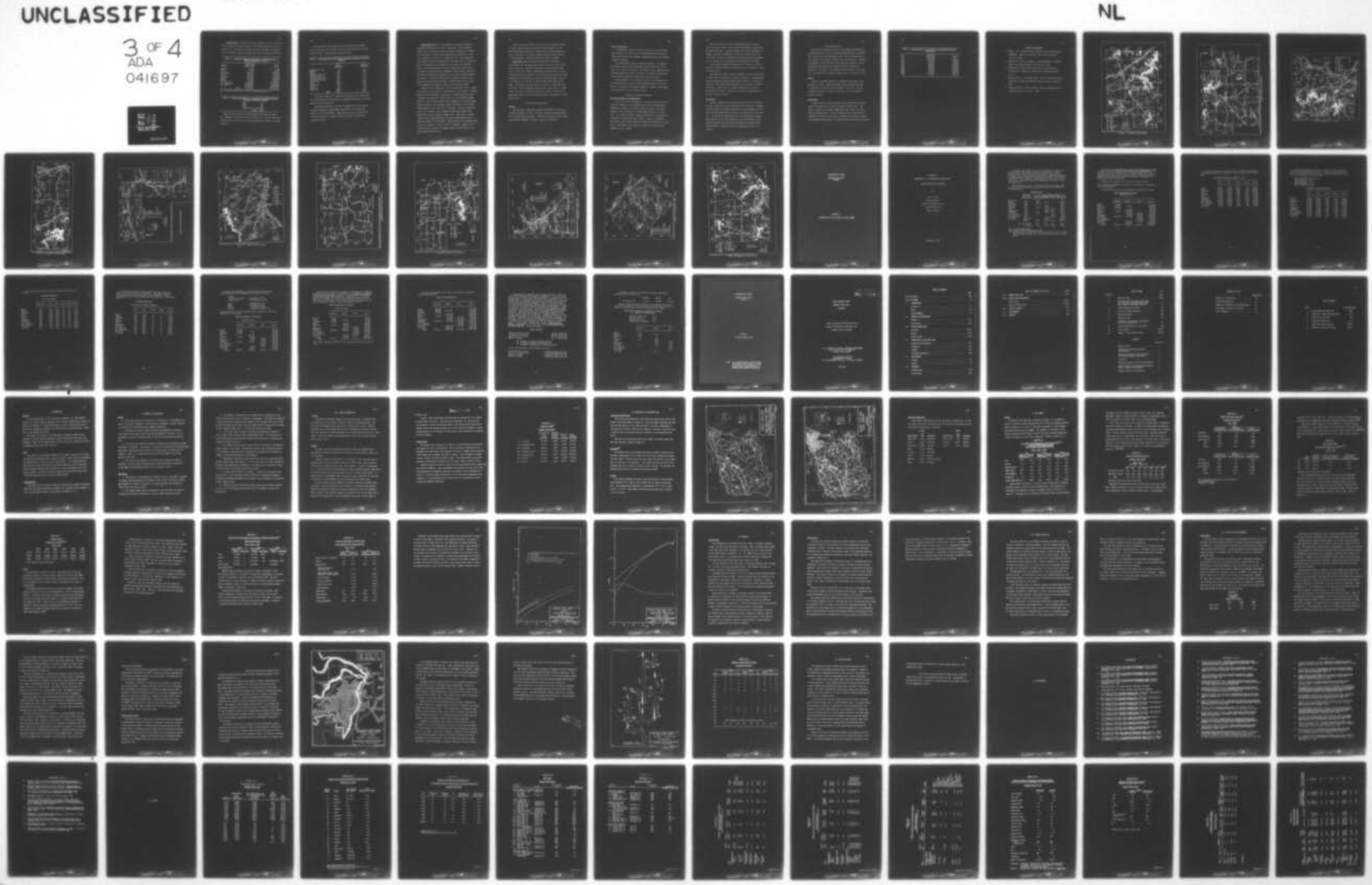

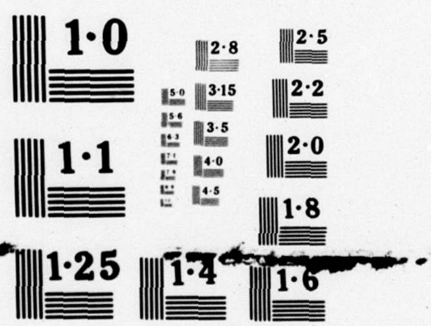
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Transportation.- Limestone products are generally low in value and are not transported great distances. Some larger plants have rail connections, but the majority are served by truck. Methods of transportation of limestone produced in Meramec River Basin are given in table 20.

TABLE 19.- Limestone production (commercial and noncommercial) in Meramec River Basin, 1952-61

County	Production (short tons)	Value
Crawford	19,207	$ 43,207
Dent	3,700	7,900
Franklin	1,652,262	1,959,721
Gasconade	256,413	335,086
Iron	451,354	477,715
Jefferson	1,216,263	1,569,204
Maries	173,348	248,008
Phelps	365,458	595,511
St. Francois 1/	6,417,855	14,340,353
Ste. Genevieve	24,320,703	33,319,161
St. Louis	36,369,722	44,223,573
TOTAL	71,246,285	$97,119,439

1/ Includes dolomite chat from lead concentrating plants.

TABLE 20.- Percent distribution of transportation methods, Meramec River Basin limestone, 1952-61

Barge	1.2
Rail	30.9
Truck	65.8
Unspecified & other	2.1
TOTAL	100.0

Uses.-Limestone products from the Meramec River Basin have many uses; aggregate for concrete and road construction is the most important. Percentage use and value of the limestone production, 1952-61, are given in table 21.

Lime and cement manufacturers are the second and third largest users of limestone, in that order. Use of these products will increase in direct ratio to population and national economy.

TABLE 21.- Percentage use of limestone - Production, Meramec River Basin 1952-61

	Tons (percent)	Value (percent)
Agricultural lime	7.0	5.7
Ballast	1.0	0.4
Cement	22.0	15.5
Chemicals and glass	3.7	7.1
Coal mine dust	0.2	0.7
Concrete and roads	30.3	31.5
Fillers and whitings	2.3	4.3
Filter beds	0.1	0.1
Lime	29.0	29.8
Poultry grit	0.2	0.9
Riprap	3.0	2.4
Smelting	0.3	0.5
Other uses	0.9	1.1
TOTAL	100.0	100.0

The fourth largest use is agricultural lime as a soil conditioner. Use of limestone for this purpose has increased rapidly since the 1930's and has not yet leveled off.

The program proposed by the Corps of Engineers for flood control and power generation in the Meramec River Basin will increase the demand for limestone products. Large quantities will be required for concrete construction, riprap, and roads for each of the proposed reservoir projects.

Mining Methods.-Most of the limestone and dolomite quarries in the Meramec River Basin are open pit operations. The overburden, usually clay or loess and a layer of weathered limestone, is removed with bulldozers or carryalls and pushed aside if possible; at times, it is necessary to place it in a worked-out area. The cleared limestone ledge is drilled with down holes with either rotary or percussion drills in types and sizes depending on the scale of the operation. Quarries with working faces in excess of 30 feet are usually worked in benches, thus giving better breakage and safer working conditions. The holes are blasted with dynamite or with fertilizer grade ammonium nitrate-fuel oil mixture; there has been a marked increase in use of the latter during the past few years. Boulders which are too large to be handled by the primary crushers are drilled and blasted.

Broken stone is loaded with a full revolving power shovel, usually diesel driven, into trucks for transportation to the crusher. Crushing plants are either portable or stationary. Portable plants are self-contained units mounted on rubber tires and can be moved by highway, subject to certain restrictions. Rock is dumped onto a grizzly feeder, undersize going to the secondary crusher and oversize to the primary. Riprap boulders can be taken off at this point. Primary crushers are either jaw or impactor type; secondary crushers are usually rolls. Agricultural lime is crushed in hammer mills. Separation is done by vibrator type screens powered by a portable diesel-electric unit if commercial power is not available. Sized products are transported from the unit by conveyor or truck to bins or stockpiles. There is an increased use for this type of equipment because several quarry sites can be worked with one unit.

Other quarries have diesel or electric driven stationary plants involving larger equipment and making a greater variety of sizes. Many have mechanized methods of storing and reclaiming crushed products. Washing the stone after crushing produces a better grade of concrete aggregate. Railroad facilities are often available.

Water Usage.-Limestone quarries operating in the Meramec River Basin do not use appreciable amounts of water in their primary quarry operations. Operations which have purchased metered water usually report from 1,000 to 2,000 gallons per month used for drinking and miscellaneous purposes. All quarries operate above the normal ground-water level and have no continuous pumping problems. Most are self draining, but some have to handle rainfall with power-driven pumps. No stream pollution problems are involved. Those with other activities, such as ready-mix concrete plants, lime plants, or cement plants, are users of measurable quantities of water. Quarries with appreciable amounts of clay and shale may find it advantageous to wash their product.

Future Production Outlook

Reserves

The limestone and dolomitic limestone formations are widely distributed throughout the area; reserves of construction-grade materials are considered almost unlimited. Urbanized zoning may preclude mining in areas where commercial limestone reserves are abundant.

Cost of Production

No appreciable change in the cost of production is anticipated. Wage increases will continue to be counterbalanced with the use of larger and more efficient equipment, cheaper explosives, and increased tonnage per manshift.

The average market price of limestone produced in the Meramec River Basin during the period 1952-1961 was $1.36 per ton, with a high of $1.52 and a low of $1.27. The market is very competitive and increased demand will cause an increase in the number of producers; prices would be expected to remain near the present level.

Future expansion of the limestone industry in the Meramec River Basin depends mainly upon an extended highway program in the area. The use of limestone in concrete, asphaltic, and gravel roads ranges from base material to the finished surface.

Economics of Limestone Industry

Production, Markets, and Employment

The low unit value of limestone and limestone products does not allow the commodity to be economically moved over great distances. Widespread occurrence of favorable formations makes it more advantageous to seek a new quarry site when demand develops in a given area. As is often the case in highway construction, a new quarry is started for a single contruction contract. There is a demand for agricultural lime in most communities allowing utilization of the fine sizes. Development of the portable crushing and screening plant implements such a program.

The major market for concrete aggregate materials is the St. Louis metropolitan area. Other crushed stone markets include use on secondary roads and as road base material and concrete aggregate for paving. The Corps of Engineers estimate that construction of the eight major and twelve intermediate reservoirs will require 795,000 tons of crushed stone for aggregate and 848,000 tons for riprap.

Stone quarries supplying raw material for cement and lime production are captive operations, and the plants are located at or near the quarry sites.

The limestone industry provided employment for about 350 persons in 1960, with a total payroll of nearly $1.6 million. Average annual wage per employee was approximately $4,550, based on a 5 percent increase over the average wage compiled by the 1958 Census of Mineral Industries. Overall value of crushed limestone sold or used in Meramec Basin counties in 1960 was $11.1 million, approximately 31 percent of the State total.

Projections

Based on projections of construction activity and the national economy, outlook for limestone production is satisfactory. Assuming continued growth of the above categories, projected demand for limestone from the Meramec Basin counties in the year 2070 is 46 million tons. On the basis of 1960 production rates, Meramec Basin employment required for the 2070 demand will total approximately 1,800. Limestone production is distributed throughout the Meramec Basin, and assignment of employees to specific geographical areas is not feasible.

Miscellaneous Stone

Two mineral concentration plants in the Meramec River Basin are treating lead and iron ores in which the gangue material is predominately igneous with some sedimentary rocks. Chats from these plants are suitable for roadstone, concrete, and railroad ballast. Reserves are dependent on the operation of such lead and iron mines. During the period 1952 through 1961, shipments totaled 5,095,568 tons (table 22). The value of the product was $2,717,555 or 53 cents per ton. Two-thirds of the tonnage is moved by rail, one-third by truck.

Marble

Marble is quarried adjacent to the Meramec River Basin in the eastern part of Ste. Genevieve and Perry Counties where formations of Ordovician and Devonian age are exposed. The stone is cut and finished into sizes for interior and exterior trim and crushed to produce terrazzo.

Water Usage

Water is used at the miscellaneous stone operations for washing and wet screening; rate of use is estimated at 600 gal./min. The water is recycled and stored in ponds which also collect the slimes from the washing process. Loss by evaporation and in the product is estimated at 25 percent; new water is supplied from streams or pumped from abandoned mine workings. No stream pollution problems are involved.

TABLE 22.- Miscellaneous stone production in Meramec River Basin, (1952-1961)

Year	Production short tons	Value
1952	1,288,200	562,131
1953	268,100	176,951
1954	88,217	85,662
1955	508,461	191,807
1956	562,067	270,363
1957	629,719	321,943
1958	454,894	276,429
1959	493,122	293,486
1960	432,364	276,646
1961	370,424	262,137

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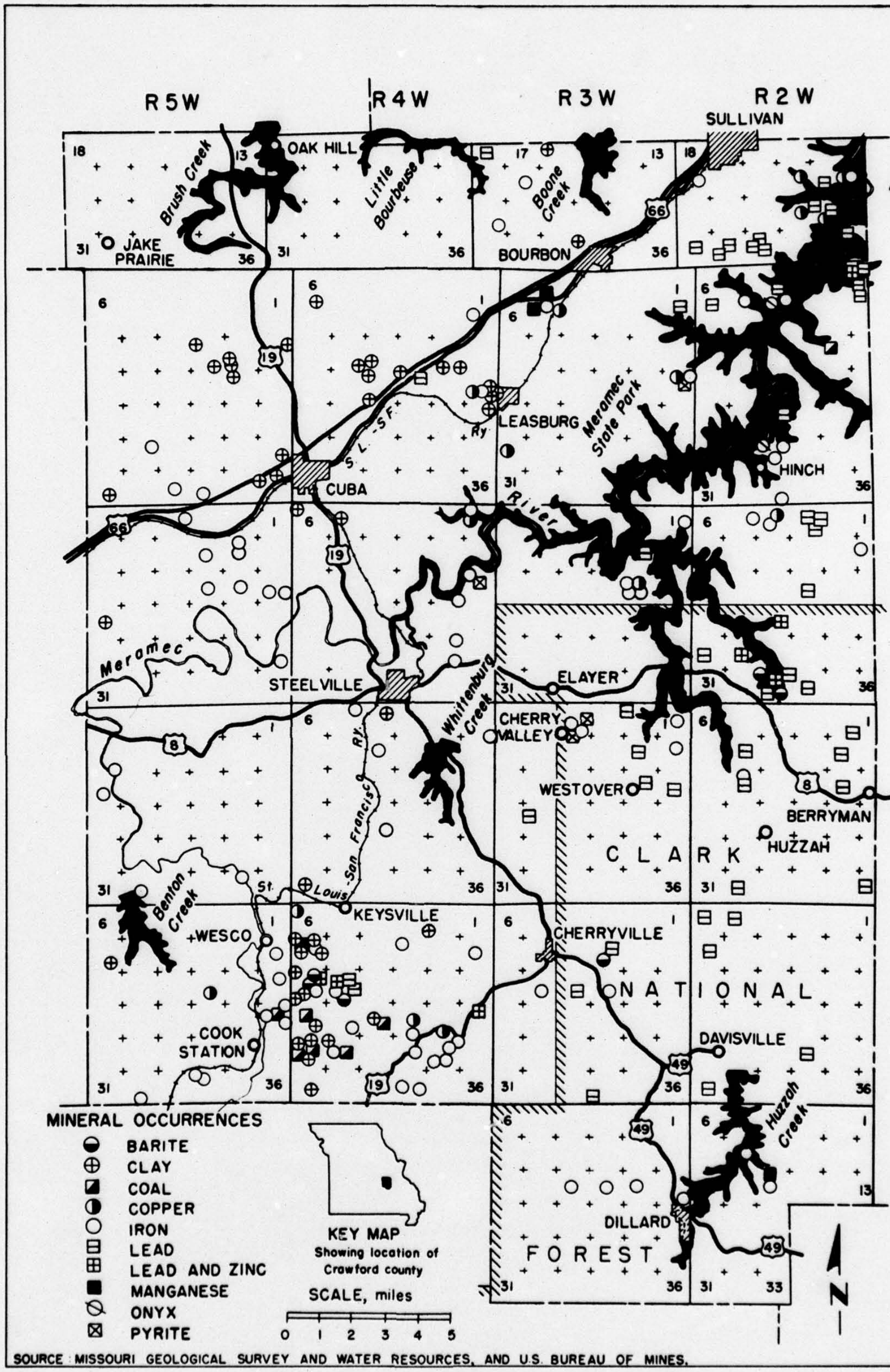


FIGURE 18.- Crawford County, Missouri

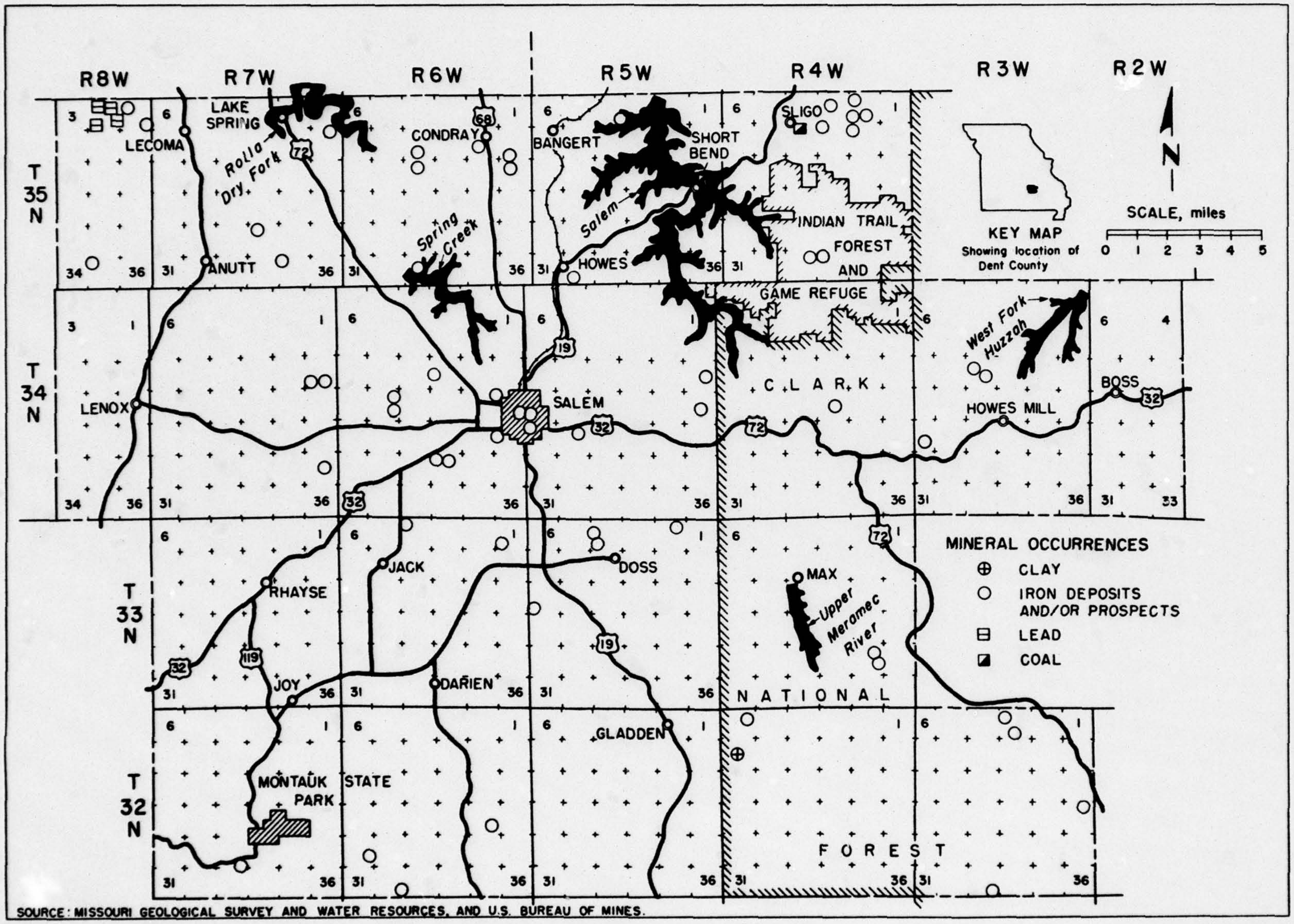
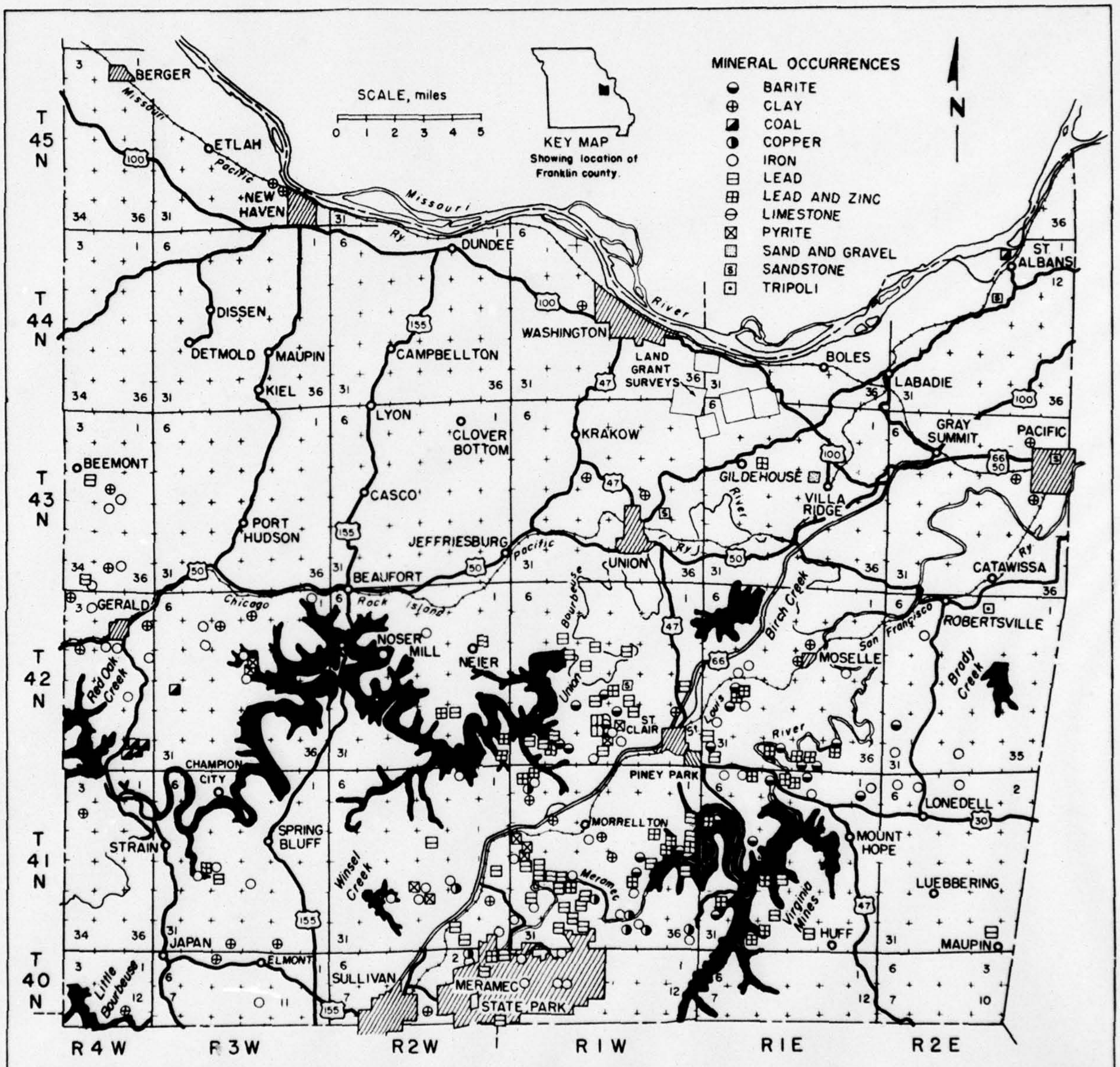
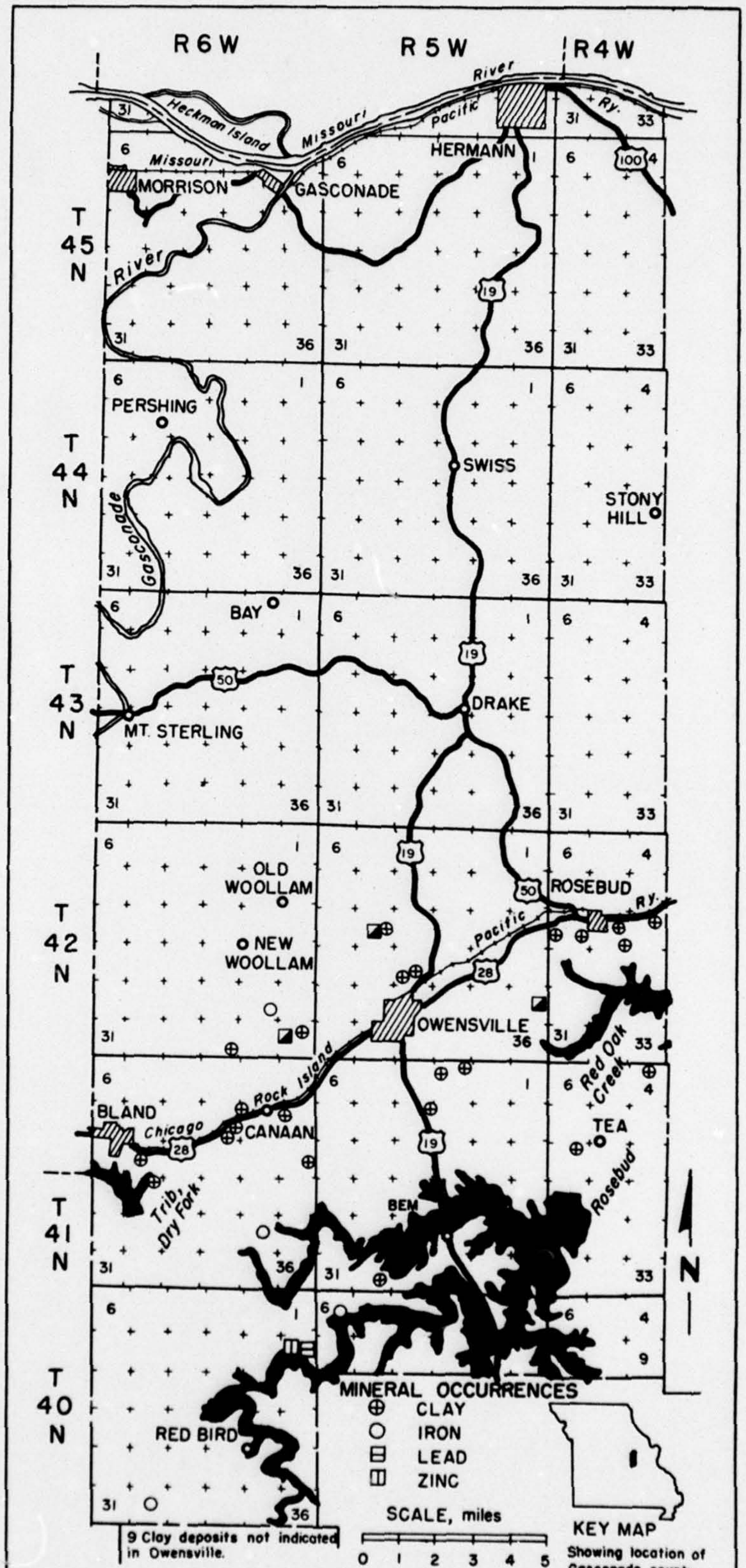


FIGURE 19.- Dent County, Missouri



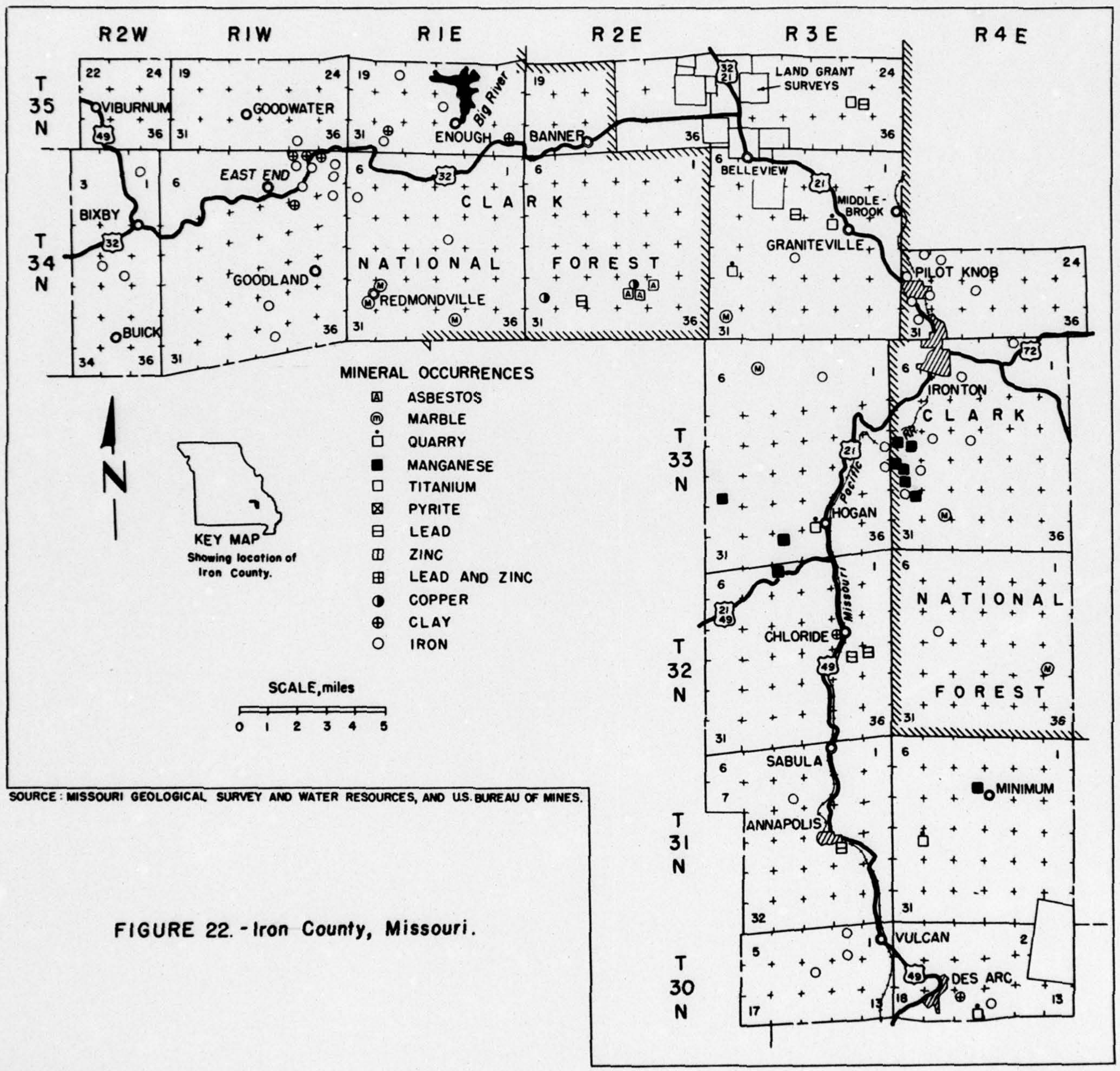
SOURCE: MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES, AND U.S. BUREAU OF MINES.

FIGURE 20.- Franklin county, Missouri



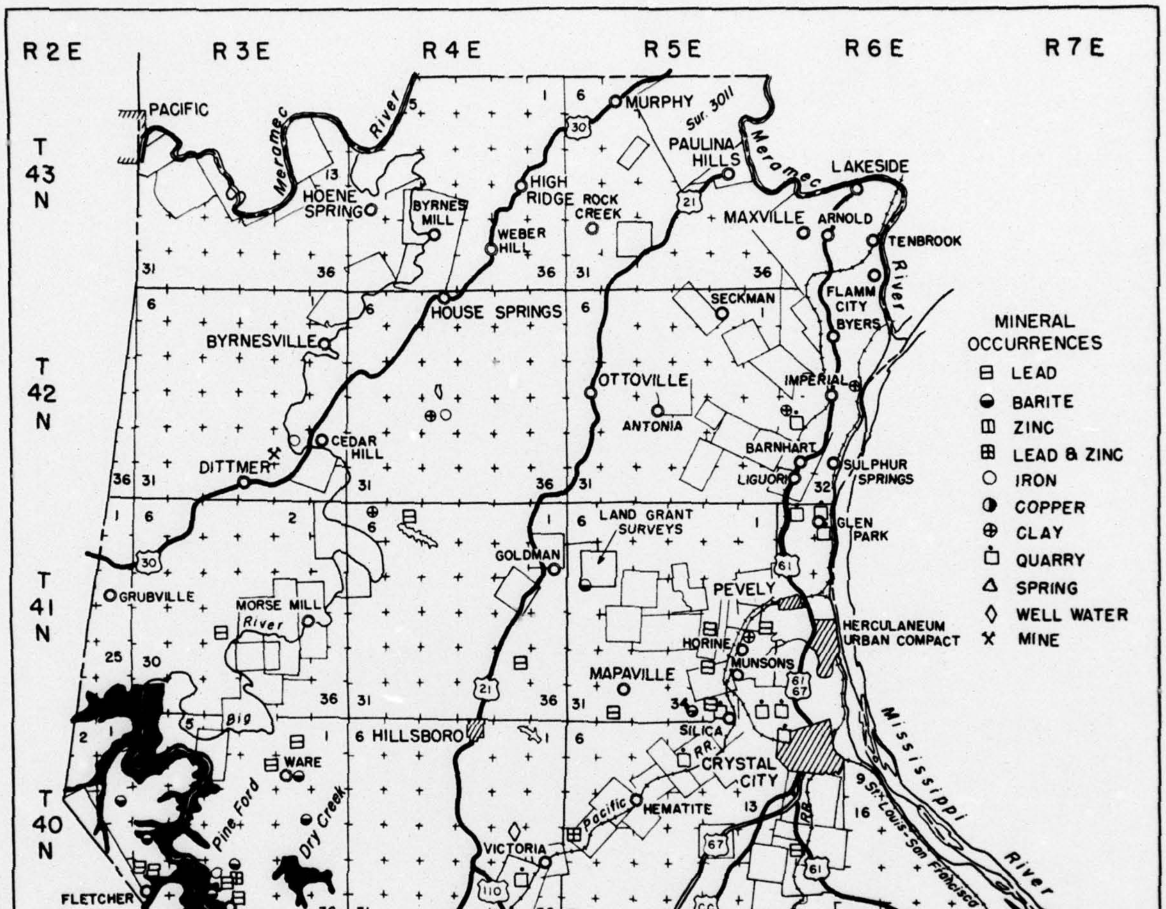
SOURCE: MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES, AND U.S. BUREAU OF MINES.

FIGURE 21.- Gasconade county, Missouri



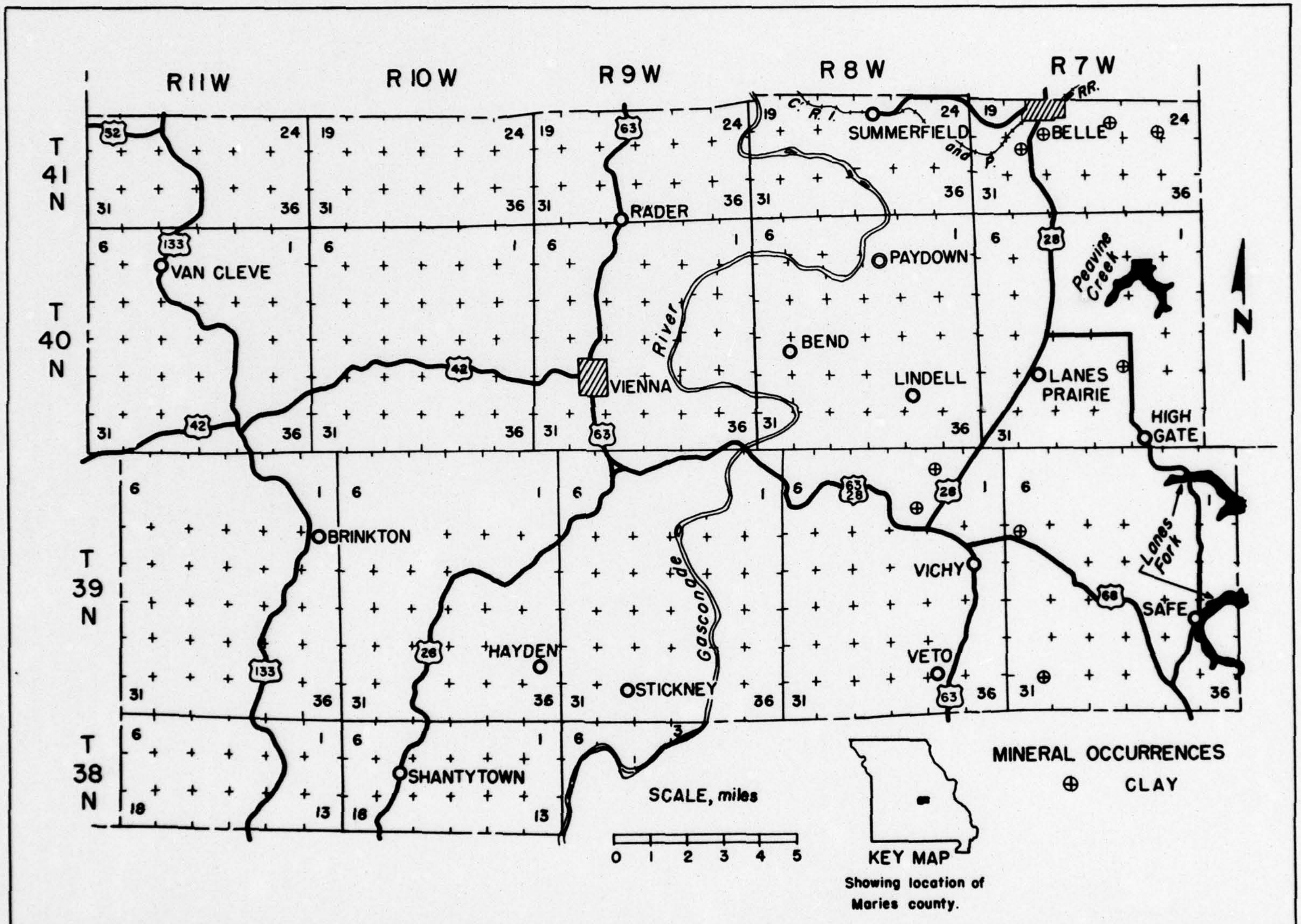
SOURCE: MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES, AND U.S. BUREAU OF MINES.

FIGURE 22. - Iron County, Missouri.



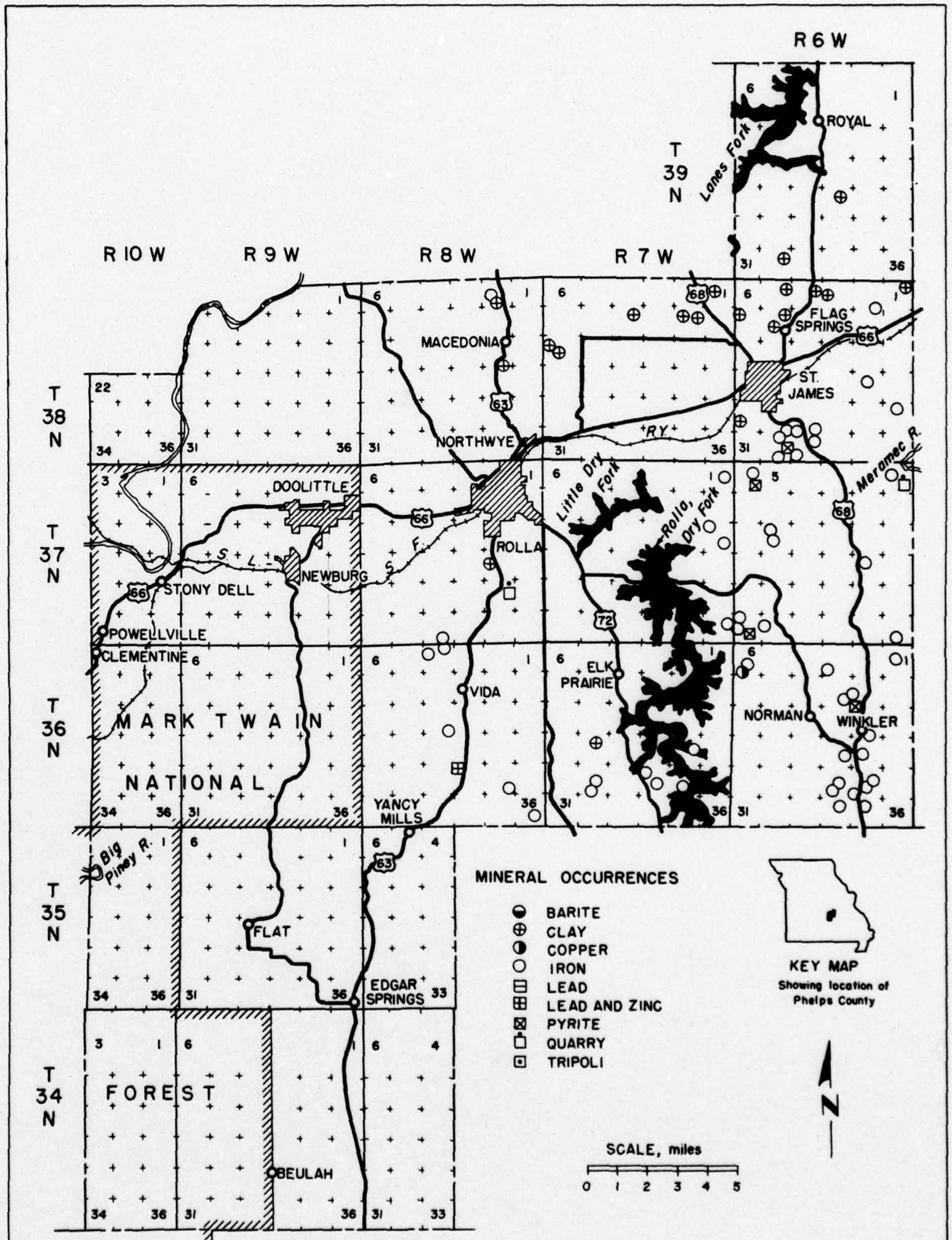
SOURCE: MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES, AND U.S. BUREAU OF MINES.

FIGURE 23. - Jefferson County, Missouri.



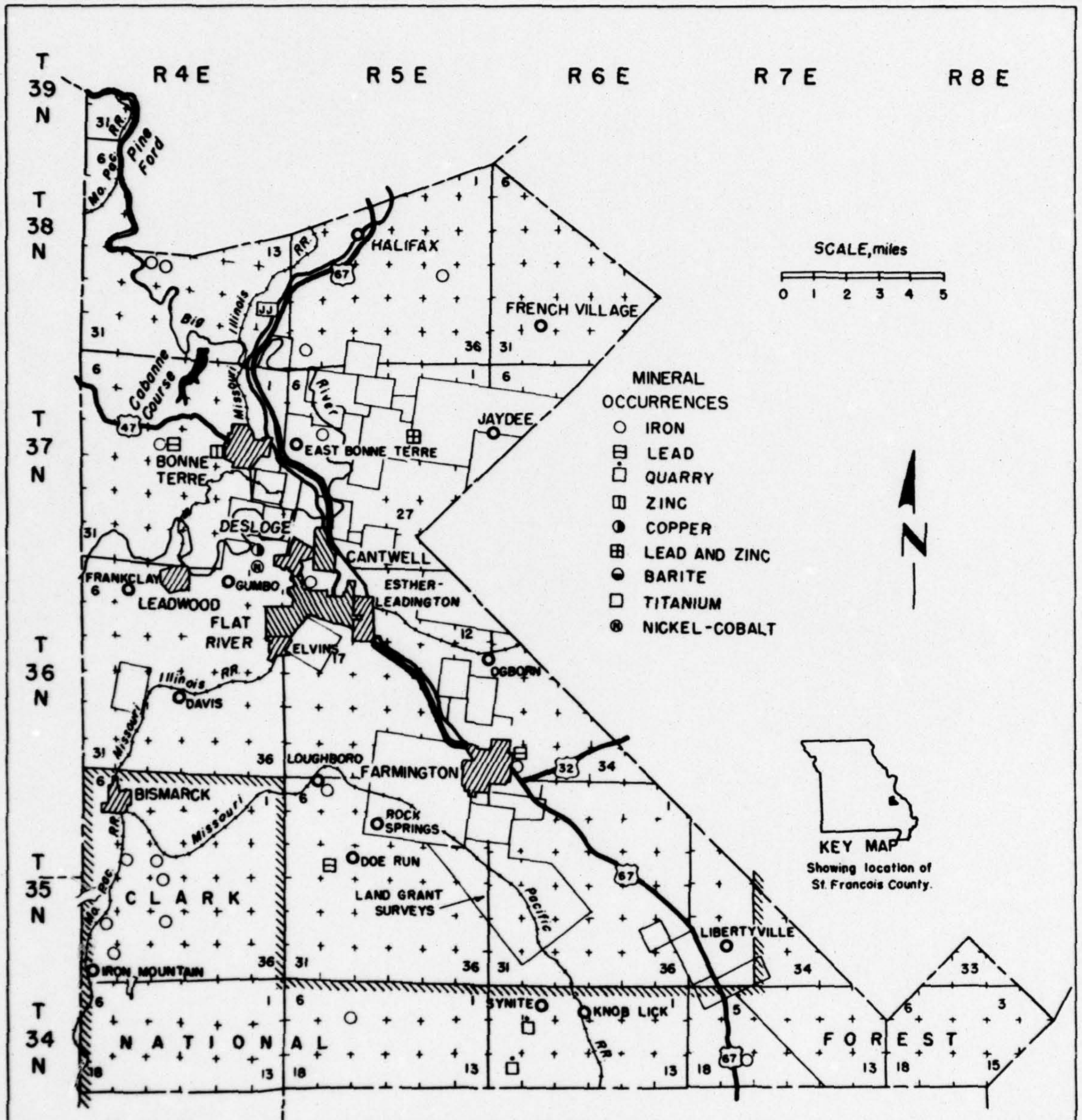
SOURCE: MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES, AND U.S. BUREAU OF MINES.

FIGURE 24.-Maries County, Missouri



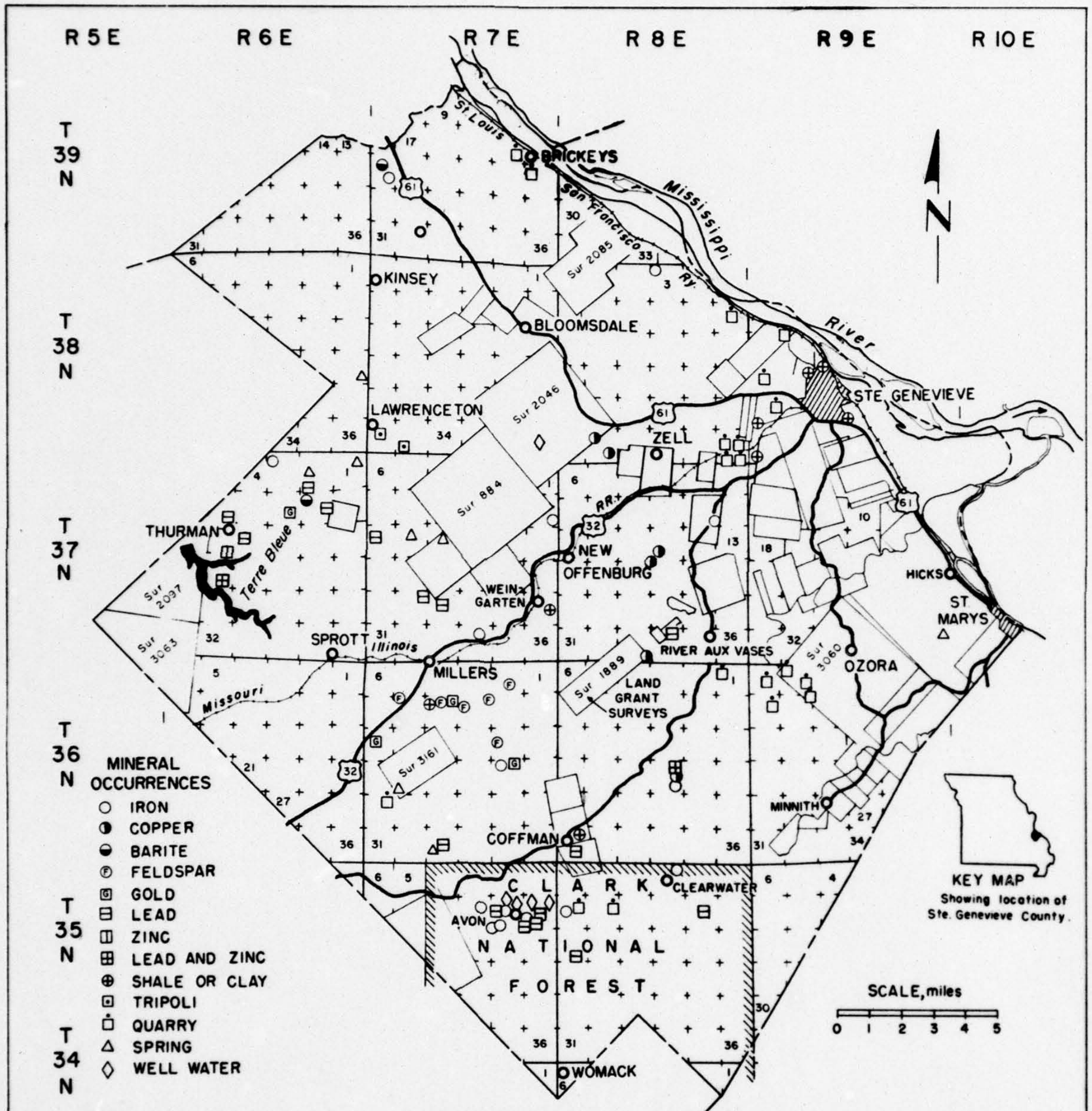
SOURCE: MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES, AND U.S. BUREAU OF MINES.

FIGURE 25.- Phelps County, Missouri



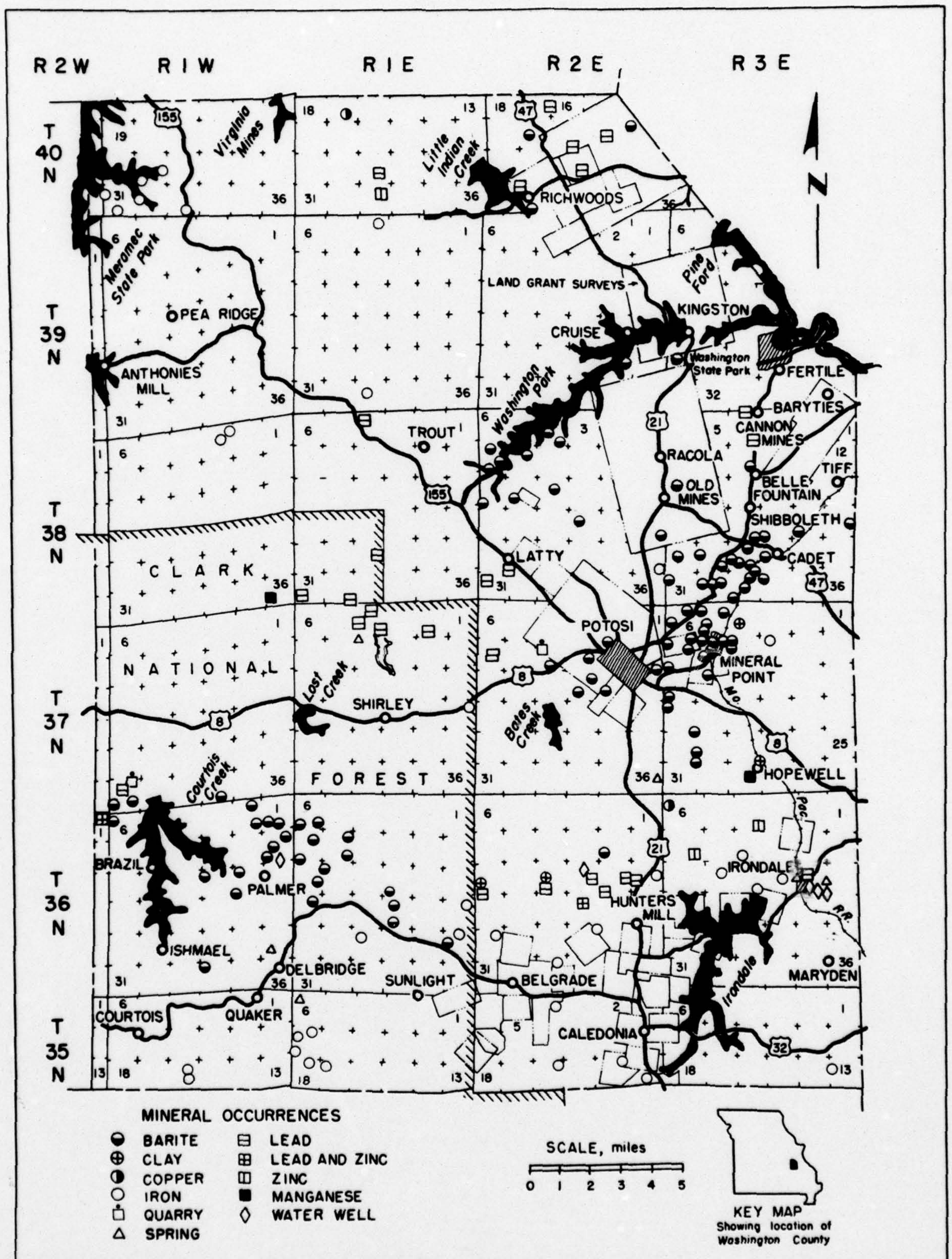
SOURCE: MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES, AND U.S. BUREAU OF MINES.

FIGURE 26.- St. Francois County, Missouri.



SOURCE: MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES, AND U.S. BUREAU OF MINES.

FIGURE 27.- Ste. Genevieve County, Missouri.



SOURCE: MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES, AND U.S. BUREAU OF MINES.

FIGURE 28.-Washington County, Missouri

COMPREHENSIVE REPORT

MERAMEC RIVER BASIN,
MISSOURI

APPENDIX K

GROUNDWATER USE AND PRODUCTION CAPABILITIES

APPENDIX K

GROUNDWATER USE AND PRODUCTION CAPABILITIES

MERAMEC RIVER BASIN, MISSOURI

by

Dale L. Fuller

Senior Geologist

Missouri Geological Survey

and Water Resources

Rolla, Missouri

December 7, 1962

The Meramec River Basin is drained by three major streams, the Bourbeuse River, the Meramec River, and the Big River. Parts of fifteen counties are drained and they are Maries, Osage, Phelps, Gasconade, Dent, Texas, Reynolds, Crawford, Iron, Washington, Franklin, St. Francois, Ste. Genevieve, Jefferson, and St. Louis. Total area of the Meramec Basin as shown by the Drainage Map of Missouri is 3,980 square miles. Population density as averaged for this report is 43.4 per square mile.

The following table gives the population density of each county and the area in square miles of each county within each sub-basin of the Meramec Basin.

MERAMEC BASIN

	Population	Area in Square Miles			
	per sq. mi.	Bourbeuse	Meramec	Big	Basin Total
Maries (a)	13.8	117.2			117.2
Phelps	37.5	82.6	176.4		259.0
Gasconade	23.5	164.7			164.7
Dent (b)	13.8		524.1		524.1
Crawford	16.6	142.7	569.0		711.7
Iron	14.5		57.7	55.7	113.4
Washington	18.9		293.0	416.1	709.1
Franklin	47.8	295.9	252.0	11.1	559.0
St. Francois	79.9			171.7	171.7
Ste. Genevieve	24.2			24.4	24.4
Jefferson	99.5		83.8	217.4	301.2
St. Louis	130.8 (c)		244.7		244.7
	Total	803.1	2,200.7	896.4	3,900.2
	As shown by map	808	2,217	955	3,980
	Error	-4.9	-16.3	-58.6	-79.8

(a) Includes Osage County
(b) Includes Texas and Reynolds Counties
(c) Population of St. Louis County is 703,532 of which 92.4% is urban. Area involved is mostly rural and an adjustment for this has been made.

The publication, Estimated Use of Water In The United States, 1960, Geological Survey Circular 456, gives rural water consumption per person as being sixty gallons per day and urban consumption as being 130 gallons per day. In this report to create a safety factor, the consumption rate of 130 gallons per day was utilized. Groundwater consumption was computed as follows:

Population per square mile X area X130 = gallons per day.

From a practical standpoint it is possible to consider all consumption as being groundwater.

The following table gives the groundwater consumption by humans.

WATER CONSUMPTIONS BY HUMANS
Gallons per day

	Bourbeuse	Meramec	Big	Total
Maries	210,210			210,210
Phelps	402,740	859,950		1,262,690
Gasconade	493,100			493,100
Dent		940,290		940,290
Crawford	307,970	1,227,850		1,535,820
Iron		108,810	104,910	213,720
Washington		719,940	1,022,320	1,742,260
Franklin	1,838,200	1,565,980	69,030	3,473,210
St. Francois			1,783,470	1,783,470
Ste. Genevieve			76,700	76,700
Jefferson		1,083,810	2,812,030	3,895,840
St. Louis		4,160,910		4,160,910
Totals	3,252,220	10,667,540	5,868,460	19,788,220

Livestock population as given by the U. S. Census of Agriculture 1959, Missouri Counties for January 1, 1959, is shown in the following table.

LIVESTOCK POPULATION, JANUARY 1, 1959

	Cattle	Hogs	Horses	Sheep	Poultry
Maries	21,615	16,433	1,297	911	62,261
Phelps	25,332	8,898	1,237	1,243	48,246
Gasconade	21,360	21,218	1,068	1,143	126,467
Dent	21,861	9,012	1,226	1,111	56,872
Crawford	23,182	17,462	1,076	1,138	40,815
Iron	9,523	5,555	521	341	17,463
Washington	17,104	7,891	539	2,052	54,100
Franklin	43,724	39,479	2,097	2,241	80,040
St. Francois	19,560	10,874	601	1,027	54,390
Ste. Genevieve	21,076	34,002	552	478	70,307
Jefferson	16,886	17,781	1,178	522	80,009
St. Louis	7,753	15,050	1,024	892	81,432

Livestock population as given by a January 1, census, because of breeding increases during the course of the year, must be adjusted to give a representative population. The following adjustments have been made and incorporated in the next table:

Cattle population + 1/2 of 80 %
Horse population none
Hog population X2
Sheep population + 20 %
Poultry population none

ADJUSTED LIVESTOCK POPULATION

	Cattle	Hogs	Horses	Sheep	Poultry
Maries	27,399	32,866	1,297	1,093	62,261
Phelps	34,087	17,796	1,237	1,492	48,246
Gasconade	27,056	42,436	1,068	1,372	126,467
Dent	27,691	18,024	1,226	1,333	56,872
Crawford	29,364	34,924	1,076	1,366	40,815
Iron	12,062	11,110	521	409	17,463
Washington	21,665	15,782	539	2,462	54,100
Franklin	55,584	78,958	2,097	2,689	80,040
St. Francois	24,778	21,748	601	1,232	54,390
Ste. Genevieve	26,696	68,004	552	574	70,307
Jefferson	21,389	35,562	1,178	626	80,009
St. Louis	9,810	30,100	1,024	1,070	81,432

In the table that follows, livestock population per square mile is shown.

LIVESTOCK POPULATION

Per Square Mile

	Square Mile	Cattle	Hogs	Horses	Sheep	Poultry
Maries	526	52.1	62.5	2.5	2.1	118.4
Phelps	677	50.3	26.3	1.8	2.2	71.3
Gasconade	520	52.0	81.6	2.1	2.6	243.2
Dent	756	36.7	23.8	1.6	1.8	75.2
Crawford	760	38.6	45.9	1.4	1.8	53.7
Iron	554	21.8	20.1	1.0	0.8	31.5
Washington	760	28.5	20.8	0.7	3.2	71.2
Franklin	932	59.6	84.7	2.2	2.9	85.9
St. Francois	457	54.2	47.6	1.3	2.7	119.0
Ste. Genevieve	500	53.4	116.0	1.1	1.1	140.6
Jefferson	667	32.1	53.3	1.8	0.9	119.9
St. Louis	497	19.8	60.6	2.1	2.2	163.9

Of the water consumed by cattle, horses and sheep, only one-fourth of the supply comes from groundwater. The water supplied to swine and poultry comes almost entirely from groundwater. The following table adjusts livestock population per square mile to the groundwater use:

LIVESTOCK POPULATION

Per Square Mile Using Groundwater

	Cattle	Hogs	Horses	Sheep	Poultry
Maries	13.0	62.5	.6	.5	118.4
Phelps	12.6	26.3	.4	.5	71.3
Gasconade	13.0	81.6	.5	.7	243.2
Dent	9.2	23.8	.4	.4	75.2
Crawford	9.6	45.9	.3	.4	53.7
Iron	5.4	20.1	.2	.2	31.5
Washington	7.1	20.8	.2	.8	71.2
Franklin	16.9	84.7	.5	.7	85.9
St. Francois	13.5	47.6	.3	.7	119.0
Ste. Genevieve	13.3	116.0	.3	.3	140.6
Jefferson	8.0	53.3	.4	.2	119.9
St. Louis	4.9	60.6	.5	.5	163.9

The Water Well Handbook of the Missouri Water Well Drillers Association lists water consumption of livestock as follows:

Cattle:	
Dry cows or steers	12 gallons per day
Milking cows	25-30 gallons per day
Hogs	2 gallons per day
Horses	10 gallons per day
Sheep	1.5 gallons per day
Poultry	4 gallons per day per 100

Twenty gallons per day is the assumed water consumption of cattle as computed in the next table:

WATER CONSUMPTION BY LIVESTOCK

Gallons Per Day

	Bourbeuse	Meramec	Big	Total
Maries	46,470			46,470
Phelps	25,788	55,072		80,860
Gasconade	72,287			72,287
Dent		125,365		125,365
Crawford	41,312	164,726		206,038
Iron		8,759	8,455	17,214
Washington		55,553	78,892	134,445
Franklin	152,862	130,183	5,734	288,779
St. Francois			64,216	64,216
Ste. Genevieve			12,371	12,371
Jefferson		23,104	59,937	83,041
St. Louis		56,673		56,673
Totals	338,719	619,435	229,605	1,187,759

The state-wide industrial consumption of groundwater is 56,000,000 gallons per day as reported in the publication, Estimated Use of Water, In The United States, 1960, Geological Survey Circular 456. Assuming on the basis of area that groundwater consumption within the Meramec Basin is the average of the state, then 3,199,920 gallons per day of groundwater is being used. The following table gives industrial groundwater consumption according to area and population density:

WATER CONSUMPTION BY INDUSTRY

Gallons Per Day

	Bourbeuse	Meramec	Big	Total
Maries	29,922			29,922
Phelps	57,304	122,378		179,682
Gasconade	71,602			71,602
Dent		133,803		133,803
Crawford	43,823	174,740		218,563
Iron		15,477	14,571	30,048
Washington		102,296	146,230	248,526
Franklin	261,664	222,851	9,816	494,331
St. Francois			253,798	253,798
Ste. Genevieve			10,924	10,924
Jefferson		154,255	400,179	554,434
St. Louis		592,126		592,126
Totals	464,315	1,517,926	835,518	2,817,759*

*This figure reflects the difference in measured area versus the "stated" area.

The table which follows is the total of groundwater consumption as previously tabulated.

TOTAL WATER CONSUMPTION

	Bourbeuse	Meramec	Big	Total
Maries	286,602			286,602
Phelps	485,832	1,037,390		1,523,222
Gasconade	636,989			636,989
Dent		1,199,458		1,199,458
Crawford	393,105	1,567,316		1,960,421
Iron		133,046	127,936	260,982
Washington		877,789	1,247,442	2,125,231
Franklin	2,252,726	1,919,014	84,580	4,256,320
St. Francois			2,101,484	2,101,484
Ste. Genevieve			99,995	99,995
Jefferson		1,261,169	3,272,146	4,533,315
St. Louis		4,809,709		4,809,709
Totals	4,055,254	12,804,891	6,933,583	23,793,728

A manuscript in preparation by the author devotes one section to recharge and discharge of groundwater in Missouri. Cited is evidence which leads to the conclusion that groundwater in an area such as the Meramec Basin is recharged by infiltration of precipitation on the land surface which is topographically higher than the main stream channels. Conversely, discharge of groundwater occurs into the major streams. This downward and upward plus lateral movement of groundwater involves not only the near surface aquifers but also the deep aquifers. Except for periods of "surface" water run-off during and immediately following periods of precipitation, stream flow is maintained by groundwater discharge. Maximum development of the groundwater resources would result in a near total use of what is now being discharged into the streams without dewatering the aquifers. Complete interception of the groundwater discharge, is not practical, not feasible, nor would it be possible. Viewed as being more feasible would be the development of groundwater use to the point where consumption would be only slightly in excess of the minimum stream flow. For this concept the date August 1, was selected. The data used is from, Surface Waters of Missouri, 1940-1949, Vol. 34, 2nd series, Missouri Geological Survey and Water Resources. This data follows:

STREAM DISCHARGE

Bourbeuse River at Union	72 (a)	second feet
Big River at Byrnesville	188 (b)	second feet
Meramec River at Eureka	792 (b)	second feet
*Meramec sub-basin	532	second feet

(a) Average of 6 gagings selected from 10
(b) Average of 8 gagings selected from 10
* Eureka-Union-Byrnesville = Meramec sub-basin

1 Cubic foot per second = 646,323 gallons per day

Bourbeuse River at Union	46,535,256 gallons per day
Big River at Byrnesville	121,508,724 gallons per day
Meramec at Eureka	511,887,816 gallons per day
Meramec sub-basin	343,843,836 gallons per day

Available groundwater for increased consumption expressed as gallons per day, is as follows:

	Bourbeuse	Meramec	Big
Per square mile	57,952	110,788	135,612

The table which follows illustrates the permissible increase of groundwater consumption. The first portion is on the basis of area and the second considers both the area and the population density.

PERMISSIBLE INCREASE OF GROUNDWATER EXPRESSED
AS A MULTIPLE OF PRESENT USAGE

Bourbeuse River Basin	X 11
Big River Basin	X 11
Meramec River Basin	X 21
Meramec River sub-basin	X 27

	Bourbeuse	Meramec	Big
Maries	X 24		
Phelps	X 10	X 19	
Gasconade	X 15		
Dent		X 48	
Crawford	X 21	X 40	
Iron		X 48	X 59
Washington		X 37	X 45
Franklin	X 7	X 14	X 17
St. Francois			X 11
Ste. Genevieve			X 33
Jefferson		X 7	X 9
St. Louis		X 6	

COMPREHENSIVE REPORT

MERAMEC RIVER BASIN,
MISSOURI

APPENDIX L

WATER RESOURCES STUDY

NOTE: THE ATTACHED REPORT ON WATER SUPPLY AND WATER QUALITY CONTROL, PREPARED BY THE PUBLIC HEALTH SERVICE, IS A WORKING DRAFT SUBJECT TO REVISION.

WORKING DRAFT
SUBJECT TO REVISION

WATER RESOURCES STUDY

MERAMEC RIVER BASIN

MISSOURI

Study of Potential Needs and Value of Water for Municipal, Industrial, and Quality Control Purposes

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VI
Kansas City, Missouri

In Cooperation with the
DEPARTMENT OF THE ARMY
U.S. Army Engineer District - St. Louis, Missouri

MAY 1963

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I. INTRODUCTION

Authority

In a letter dated May 8, 1961, the District Engineer, U.S. Army Engineer District, St. Louis, Missouri, requested the U.S. Public Health Service, Region VI, Kansas City, Missouri, to evaluate and prepare a report indicating the need for and value of storage for municipal and industrial water supply and quality control water in the Meramec River Basin.

The request was pursuant to the Memorandum of Agreement between the Department of the Army and the Department of Health, Education and Welfare dated November 4, 1958, and the Federal Water Pollution Control Act, Public Law 84-660, as amended by Public Law 87-88, July 1961.

Scope

This study is a preliminary evaluation of the need for and value of storage for municipal and industrial water supply and quality control water in the Meramec River Basin which is located in east central Missouri. The computations have been made on the basis that thirty-one proposed reservoirs will be constructed and the proposed operating plan outlined by the Corps of Engineers will not be greatly altered. The study covers the present water uses for the base period of 1970 and projected needs to the years 2020 and 2070.

Acknowledgments

This study was made possible through the cooperation and support of Federal, State and local agencies which were contacted for information and assistance. A list of these agencies appears in the Appendix as Exhibit No. 12.

II. SUMMARY AND CONCLUSIONS

Summary

1. Thirty-one reservoirs are proposed for construction in the Meramec River Basin by the Corps of Engineers. Seven are major impoundments, and the remaining are classified as intermediate and/or headwater reservoirs.

2. The need for storage in these reservoirs for municipal and industrial water supplies and quality control water was determined for the basin. The requirements are given for the base period of 1970 and future periods of 2020 and 2070.

3. The future water needs were based on an analysis of the potential economic development of the basin. The economy of the basin is diversified with manufacturing, agriculture, mining and related services in the upper part of the basin and the complex St. Louis Standard Metropolitan Statistical Area (SMSA) in the lower portion of the basin.

4. The location and boundaries of the study area coincide with those of the basin. The study area was divided into two sub-areas which are referred to as the Upper and Lower Meramec Basins (Refer to Figures 1 and 2).

Conclusions

1. The portion of the Meramec Basin located in the St. Louis SMSA is expected to increase from approximately 92 thousand in 1960 to about two million by 2070. The remainder of the basin is expected to increase from about 120 thousand in 1960 to about one million by 2070.

2. The largest single water using industry in the basin will be a 300 ton per day pulp mill which is expected to locate and begin operations by 1970.

3. The quantity of ground water in the Upper Basin is sufficient to meet present and future municipal and industrial requirements. The demands are expected to reach eight million gallons per day (mgd) by 1970, 38 mgd by 2020, and 117 mgd by 2070. The water quality meets the Public Health Service Drinking Water Standards; however, hardness ranges from 73 to 446 parts per million as $CaCO_3$.

4. In the Lower Basin, municipal and industrial demands are expected to reach 17 mgd by 1970, 93 mgd by 2020, and 400 mgd by 2070. By utilizing all of the available ground and uncontrolled surface water resources in the Lower Basin, a demand of 50 mgd can be met.

5. The primary need for quality control water is to maintain a satisfactory oxygen content in the streams. Existing data indicate that the chemical quality of the streams is satisfactory and chlorination of treatment plant effluents is assumed to satisfy bacteriological considerations.

6. The greatest demand for quality control water will be in the Lower Basin with an average annual requirement of 77 cfs by 1970, 297 cfs by 2020, and 560 cfs by 2070. The average annual requirement in the Upper Basin is expected to reach 35 cfs by 1970, 67 cfs by 2020, and 118 cfs by 2070.

7. No water supply benefits are expected to accrue to the project in the Upper Basin. In the Lower Basin the most economical alternative to storage in a Federal multipurpose impoundment has an annual value of $640,000 for the 50 year project payment period.

8. The annual value of storage for quality control has not been determined due to a lack of hydrological and reservoir cost data needed to evaluate the alternatives.

III. PROJECT DESCRIPTION

Location

The Meramec River Basin, comprising 3,952 square miles, is located in the east-central part of the State of Missouri, south of the Missouri River. The main stem of the Meramec River rises in the northern part of the St. Francois mountains on the Ozark plateau and flows in a northeasterly direction for about 200 miles, emptying into the Mississippi River 20 miles below the City of St. Louis. Figure 1 shows the location of the Meramec River Basin, the sub-basins and proposed reservoir sites.

History

The first studies of the Meramec River Basin began about 1880 and since that time many studies and reports have been made by various Federal, State, and local agencies.

Pursuant to the River and Harbor Act of January 21, 1927, the Army Corps of Engineers made a series of studies known as the "308" reports, which considered flood control, navigation, water power, and irrigation. A report on the Meramec River, published in 1930 as House Document No. 686, recommended against improvements in the Meramec Basin at that time because of lack of economic justification. A detailed plan for the Meramec Basin, consisting of three reservoirs, was presented to the public in 1949; however, the plan was deferred for further study.

In June of 1958, the local Chambers of Commerce organized the Meramec Basin Corporation. Under the auspices of the corporation, the Meramec Basin Research Project was financed to secure an unbiased, comprehensive study of the Meramec's water resources. The study was completed in December, 1961, and the final report entitled "The Meramec Basin - Water and Economic Development" was published in

SUBJECT TO REVISION

February 1962.

In April, 1960, Congressional authorization was obtained for a new comprehensive study of the basin. The Army Corps of Engineers, St. Louis District, was requested to review all previous reports on the Meramec River Basin and determine whether the proposed projects for the basin should be modified to insure maximum benefits in the interest of flood control, water conservation, navigation and other purposes.

Present Study

The present study includes all or parts of 15 counties which are drained by the Meramec River and its tributaries. The two principal tributaries are the Bourbeuse River (828 square miles drainage; 128 miles in length) and the Big River (1,021 square miles drainage; 130 miles in length). Minor branches are Huzzah, Courtois, Indian, Dry Fork, and Brazil Creeks. The maximum width of the entire watershed is approximately 80 miles and the maximum length is about 105 miles.

Currently, thirty-one reservoir sites are being invesitgated from an engineering and economic standpoint. Major impoundments are proposed for seven of the sites and intermediate and headwater reservoirs are proposed for the remaining sites. Table No. 1 gives the names and capacities of the seven major impoundments and Exhibit No. 1 in the Appendix depicts similar data for the twenty-four intermediate and headwater reservoirs.

Table No. 1

Reservoir Data[18]

Meramec River Basin

	Flood Control Pool Storage Acre-Feet	100-Year Sediment Storage Acre-Feet	Joint-use Pool Acre-Feet	Total Storage Acre-Feet
No. 2A Pineford	196,700	11,986	76,314	285,000
No. 5 Washington Park	98,110	5,588	43,467	147,165
No. 9 Irondale	106,160	5,832	49,608	161,000
No. 40 Virginia Mines	139,730	8,974	101,296	250,000
No. 17 Meramec Park	581,560	18,251	400,189	1,000,000
No. 27 Salem	104,965	5,985	50,200	161,000
No. 29 Union	355,630	11,900	160,470	528,000

IV. DESCRIPTION OF THE STUDY AREA

Location and Boundaries

The location and boundaries of the study area coincide with those of the Meramec River Basin (Refer to Figure 1). The river basins adjoining the study area are the Missouri to the north, Gasconade to the west, Mississippi to the east and the Current, Black and St. Francis to the south. The study area is divided into two sub-areas which are referred to as the Upper and Lower Basins.

The Upper and Lower Basins differ with respect to economy, growth rate and water resources. (Refer to Figure 2).

Geography[19/]

The Northern part of the Meramec River Basin is gently rolling and predominantly agricultural; to the south, the land becomes progressively rougher and more wooded. Elevation above sea level ranges from 400 feet in the northease to 1,400 feet in the southwest. The streams are swift and clear in the southern area and are generally located in narrow valleys. To the north, the Bourbeuse River and its tributaries are slower and turbid.

Climate

The climate throughout the basin is generally uniform, with an average annual rainfall of 37 inches in the northeast and 42 inches in the southwest. The average annual temperature is approximately 56° F. with a range from 0° F. to 90° F. The average frost-free growing season has a duration of about 210 days.

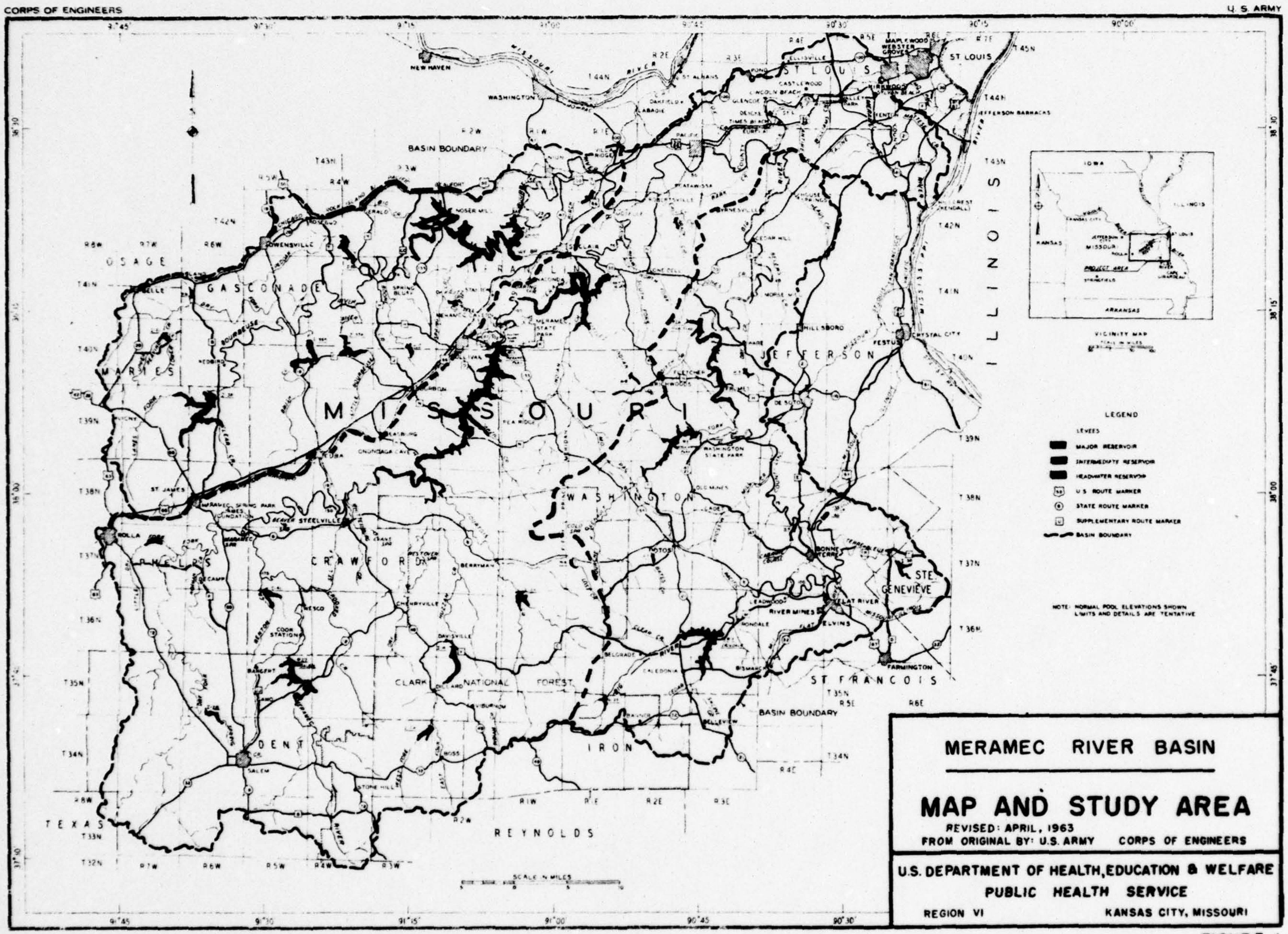
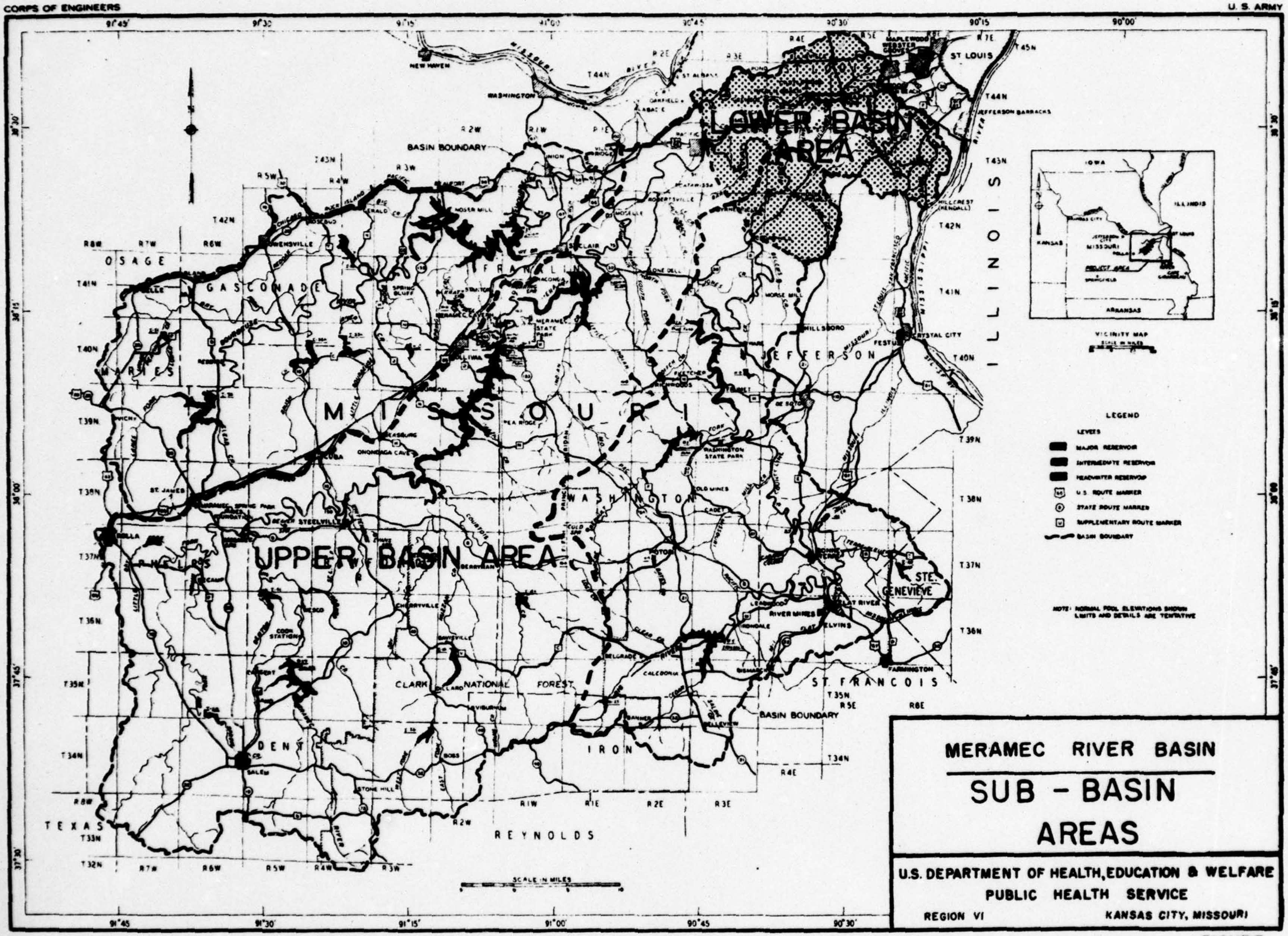

CORPS OF ENGINEERS
U. S. ARMY
MERAMEC RIVER BASIN
MAP AND STUDY AREA
REVISED: APRIL, 1963
FROM ORIGINAL BY: U.S. ARMY CORPS OF ENGINEERS
U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VI
KANSAS CITY, MISSOURI
LEGEND
LEVEES
MAJOR RESERVOIR
INTERMEDIATE RESERVOIR
HEADWATER RESERVOIR
U.S. ROUTE MARKER
STATE ROUTE MARKER
SUPPLEMENTARY ROUTE MARKER
BASIN BOUNDARY
NOTE: NORMAL POOL ELEVATIONS SHOWN LIMITS AND DETAILS ARE TENTATIVE
VICINITY MAP
IOWA
ILLINOIS
KANSAS
MISSOURI
PROJECT AREA
ARKANSAS
MISSOURI
ILLINOIS
ST LOUIS
JEFFERSON
WASHINGTON
CRAWFORD
PHELPS
DENT
IRON
REYNOLDS
TEXAS
OSAGE
GASCONADE
MARIES
ST FRANCOIS
STE. GENEVIEVE
CLARK NATIONAL FOREST
BASIN BOUNDARY
NEW HAVEN
WASHINGTON
HILLSBORO
CRYSTAL CITY
FARMINGTON
FLAT RIVER
ROLLA
SALEM
STEELVILLE
ST JAMES
OWENSVILLE
JEFFERSON BARRACKS
SCALE IN MILES

FIGURE I



MERAMEC RIVER BASIN

SUB - BASIN AREAS

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
PUBLIC HEALTH SERVICE
REGION VI KANSAS CITY, MISSOURI

FIGURE 2

Principal Communities

The principal municipalities in the study area are shown below. In the Lower Basin, the study area includes many unincorporated areas which are part of the heavily populated St. Louis SMSA.

UPPER			LOWER		
Municipality	1960 Pop.	Sub-basin	Municipality	1960 Pop.	Sub-basin
Bonne Terre	3,219	Big River	Valley Park	3,452	Meramec
Potosi	2,805	Big River	Kirkwood	29,241	Meramec
River Mines	12,000	Big River	Pacific	2,795	Meramec
Rolla	11,132	Meramec			
St. Clair	2,711	Bourbeuse			
Salem	3,870	Meramec			
Sullivan	4,098	Meramec-Bourbeuse			
Union	3,937	Bourbeuse			

V. THE ECONOMY

Present

The Meramec River Basin has a diversified economy. The northeastern portion of the basin, which includes parts of St. Louis and Jefferson Counties (Refer to Figure 1), is a part of the heavily populated St. Louis Standard Metropolitan Statistical Area (SMSA). The remainder of the basin is less heavily populated and the economy is based on services, manufacturing, agriculture, and mining, in that order of importance. (Refer to Table No. 2).

Table No. 2

The Number and Percentage of the Labor Force[1,2,3/] by Major Classifications in the Upper Meramec River Basin Counties

1940 - 1950 - 1960

	1940		1950		1960	
	Number (Thousands)	Percent	Number (Thousands)	Percent	Number (Thousands)	Percent
Farm	16.8	29.0	14.1	25.0	7.1	12.0
Mining	3.8	7.0	3.9	7.0	3.1	5.0
Manufacturing	7.6	13.0	11.9	21.0	15.3	26.0
TOTAL BASIC	28.2	49.0	29.9	53.0	25.5	43.0
TOTAL SERVICE	24.7	43.0	24.2	43.0	31.6	52.0
Unemployed	4.1	8.0	2.0	4.0	3.2	5.0
TOTAL LABOR FORCE	57.0	100.0	56.1	100.0	60.3	100.0

Approximately 60 percent or 1.5 million acres of the Basin is forested, amounting to about 7 million cords of growing stock. Sixty percent is in poletimber; the remaining 40 percent in sawtimber (Refer to Table No. 3, Page V-3). Poletimber is used primarily for fuelwood, posts and construction.

Sawtimber is used for hardwood flooring, lumber, veneer, and cooperage. Employment related to timber resources is estimated at approximately 600, or about one percent of the total labor force in the Upper Basin.

Iron, lead, zinc, barite, clay, limestone, sand and gravel of commercial value are available in the basin. In 1960, over 3,000 persons were employed in mining, approximately 2,300 in lead and iron ore extraction in St. Francois County. During the past ten years, the dollar value of mineral production ranged from the low of approximately $44.4 million in 1958 to the high of approximately $60.8 million in 1956 (adjusted to the 1954 value of the dollar). Reduction in lead mining activities was largely responsible for this decrease. Over 50 percent of this value was earned in St. Francois County (Refer to Table No. 4 [7,8,9,10]).

Table No. 4

Values of Minerals Extracted

Meramec River Basin

1954 - 1960
(Millions of Dollars)*

	1954[7]	1955[7]	1956[8]	1957[8]	1958[9]	1959[9]	1960[10]
St. Francois County	34.4	39.8	38.6	33.7	24.9	23.5	23.8
Remainder of Basin	16.6	18.0	22.2	19.8	19.5	21.7	21.4
TOTAL	51.0	57.8	60.8	53.5	44.4	45.2	45.2

*Adjusted to the 1954 value of the dollar

Employment in manufacturing has more than doubled in the past twenty years, (Refer to Table No. 2), and is a major factor in the economy of the basin, employing in 1960 an estimated 15,000 persons, or approximately

Table No. 3

Timber Resources Available[4/]

Meramec River Basin*

1959 - 2060

	1959		
	Poletimber (Thousand Cords)	Sawtimber (Million Board Feet)	Total (Thousand Cords)
Softwoods	320	152	625
Hard Hardwoods	3,660	1,150	5,960
Soft Hardwoods	115	75	265
TOTAL	4,095	1,377	6,850
Percent	60.0	40.0	100.0

	2060		
	Poletimber (Thousand Cords)	Sawtimber (Million Board Feet)	Total (Thousand Cords)
Softwoods	800	430	1,660
Hard Hardwoods	6,330	1,950	10,230
Soft Hardwoods	380	175	630
TOTAL	7,510	2,555	12,520
Percent	60.0	40.0	100.0

*U. S. Department of Agriculture, Forest Service
North Central Region
Milwaukee, Wisconsin

26 percent of the total labor force. Forty-seven percent of the manufacturing employment was in nondurables, principally leather and leather products.[1,2,3]

Agriculture consists primarily of the production of livestock and livestock products. In 1960, three-fourths of the $45.6 million total agricultural sales was obtained from livestock and its products. (Refer to Table No. 5)[11,12,13] Agricultural employment has been decreasing, from 16,743 in 1940 to 6,905 in 1960.

Table No. 5

Agricultural Data

Meramec River Basin Counties[11,12,13]

1950 - 1959

	Number Farms	Cropland Harvested (Acres)	Value of Livestock & * Livestock Products (Millions of Dollars)	Value of All * Crops Sold (Millions of Dollars)
1950	18,246	565,499	27.3	36.1
1954	16,363	521,167	24.4	32.9
1959	12,771	466,756	34.2	45.6

*Adjusted to the 1954 value of the dollar

The total Meramec Basin population has increased from approximately 121,000 in 1910 to about 212,000 in 1960. The major growth occurred in St. Louis and Jefferson Counties--from an estimated 16,000 in 1910 to an estimated 92,000 in 1960. During this period the basin's urban population increased from about 4,000 persons to approximately 45,000. The rural population increased from approximately 116,000 to about 167,000. (Refer to Table No. 6).

Table No. 6

Population Data

Meramec River Basin[14,15]

1910 - 1960

	1910	1920	1930	1940	1950	1960
Rural*	116,630	105,476	96,221	104,873	110,342	167,486
Urban*	4,613	9,264	12,177	16,879	30,171	44,320
TOTAL	121,243	114,740	108,397	121,752	140,513	211,806

*U.S. Bureau of Census definition

Future

The proximity of the basin to the St. Louis SMSA will have the most significant effect on its future growth. Expansion of the St. Louis SMSA will be felt throughout the basin either through home and industrial sites or the provision of food, minerals, forest and manufacturing for the increased market.

The expected regional and national increases in demands for forestry products will be met in part by the Meramec Basin. The U.S. Forest Service expects an increase in the basin in sawtimber production from the present cutting of 27 million board feet annually to a projected 80 million board feet annually by 2060. A 300 ton pulp mill, employing 100 persons, is expected to locate in the basin and begin operations by 1970. Total employment in the lumber and timber operations is expected to increase to about 1200 persons by 2070.[4]

Lead production is expected to increase from approximately 100,000 tons in 1960 to about 220,000 tons in 2000. The reserves are then expected to begin phasing out and may be exhausted by 2020. However, there are deposits of lead in the White River Basin directly to the south which should continue to support an employment of about 3,000 from 2020 to 2070.

Barite production is expected to increase from about 180,000 tons in 1960 to about 270,000 by 2000. The barite reserves should then phase out and be exhausted by 2020. Employment is expected to reach a peak of approximately 500 by 2000.

Iron ore extraction is expected to increase at a rate of one percent per year compounded, and reach about 10 million tons annually by 2070 from its 1960 production of 232,000 tons. Employment in this category is expected to reach a peak of about 3,000 by 2070.

Limestone, clay, sand and gravel production are also expected to increase, with employment gradually increasing from approximately 500 in 1960 to about 1,000 by 2070. Table No. 7 shows production and employment projections in the mining category.[6]

Table No. 7

Production and Employment Projections in Mineral Extractions* 6/

Meramec River Basin

1960 - 2000 - 2070

	1960		2000		2070	
	Production (Tons)	Employment	Production (Tons)	Employment	Production (Tons)	Employment
Lead	103,904	*	220,000	3,000	-	3,000
Barite	180,702	*	270,000	500	-	-
Iron	232,619	*	2,150,000	700	10,000,000	3,000
Sand & Gravel	1,500,000	*	3,500,000		5,200,000	

*Data Unavailable

Manufacturing employment in the basin counties, excluding St. Louis and Jefferson Counties, is expected to increase from approximately 15 thousand in 1960 to 48 thousand in 2020 and over 100 thousand in 2070. The major increases will be in the categories of leather and leather products, fabricating metals, machinery, vehicles, textile and apparel, food and kindred products. (Refer to Table No. 8, Page V-8).

Agricultural production in the basin is expected to increase. Farm output is expected to increase about 300 percent by 2070, with the major portion of this production being utilized in the St. Louis SMSA. In response to a continual increase in technology, agricultural employment is expected to decrease from about 6,900 in 1960 to 4,500 in 2070.

Table No. 8

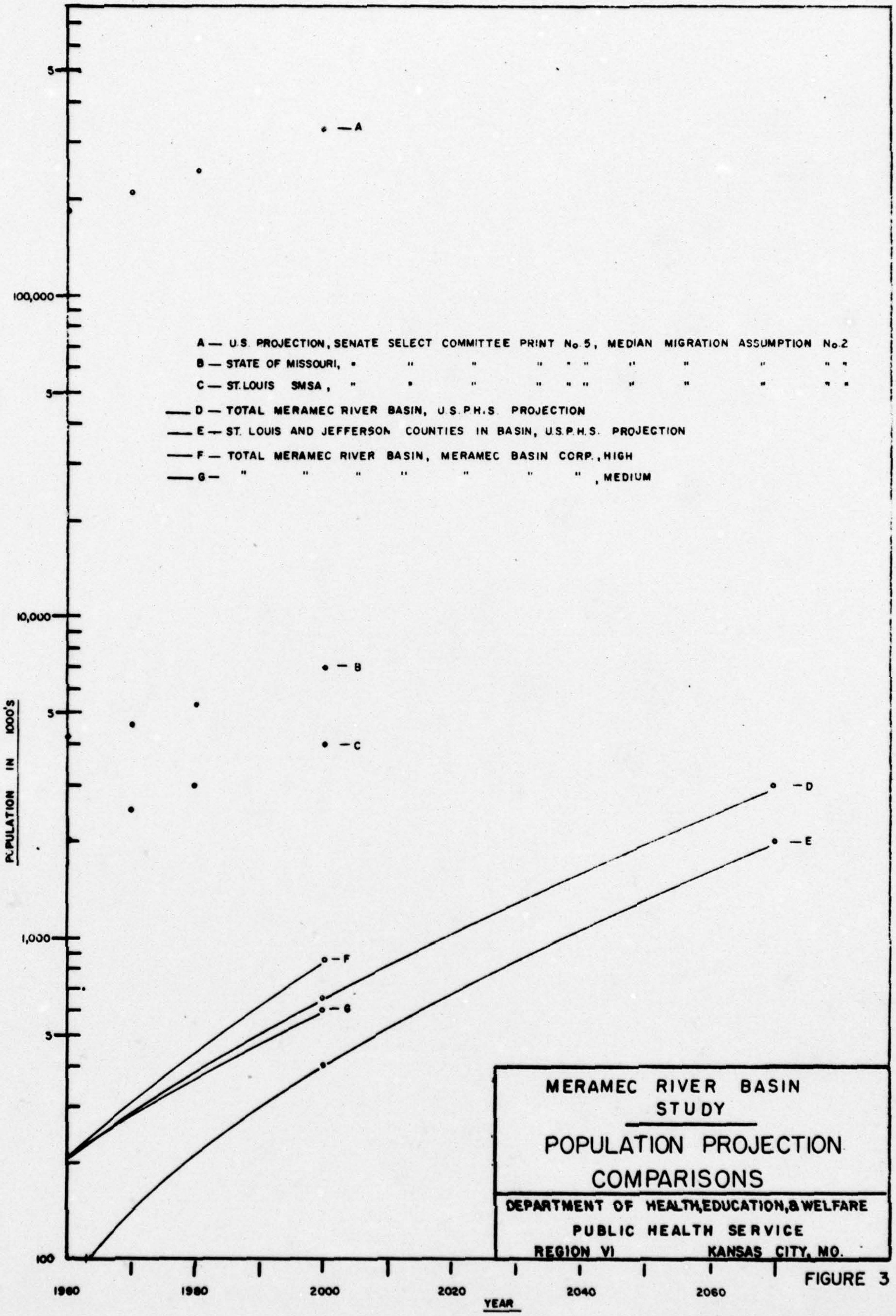
Projected Employment of Labor Force

Upper Meramec River Basin Counties*

2020 - 2070

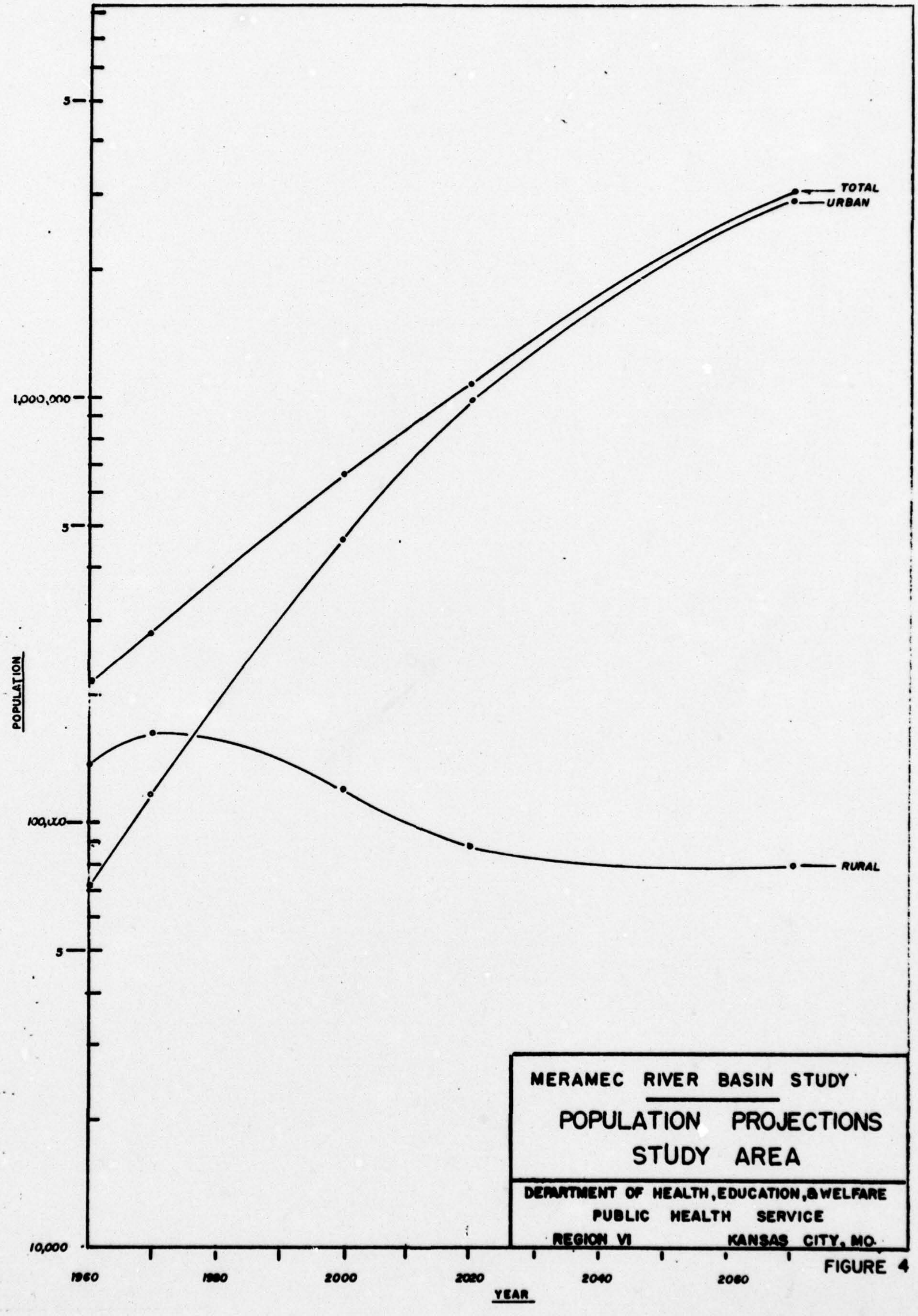
	2020		2070	
	Number (Thousands)	Percent of Labor Force	Number (Thousands)	Percent of Labor Force
Farm, Forestry & Fisheries	6.0	4.0	5.5	1.0
Mining	6.0	4.0	7.5	2.0
Manufacturing	48.0	30.0	102.0	29.0
Furniture, Lumber & Wood Products	-	(1.0)	-	(1.0)
Fabricating, Metal, Mach., Vehicles & Other Durables	-	(2.0)	-	(10.0)
Food & Kindred	-	(2.0)	-	(3.0)
Textile & Apparel	-	(3.0)	-	(3.5)
Other Nondurables	-	(11.0)	-	(10.0)
Miscellaneous	-	(5.0)	-	(1.5)
TOTAL BASIC	60.0	38.0	115.0	32.0
TOTAL SERVICE	95.0	59.0	255.0	65.0
Unemployment	5.0	3.0	10.0	3.0
TOTAL LABOR FORCE	160.0	100.0	350.0	100.0

Population in the Meramec Basin, particularly that portion which is located in the St. Louis SMSA, is expected to have significant growth. The portion of the basin that is located in the St. Louis SMSA should be mainly residential with some activity in the commercial and light industry field. These residents' primary place of employment will be in the City of St. Louis. Therefore, for the purposes of this report, this growth was considered only in terms of population. The Lower Basin is expected to increase from approximately 92 thousand in 1960 to about two million in 2070. The remainder of the basin is expected to increase from about 120 thousand in 1960 to about one million in 2070, of which 80 thousand should be rural and 920 thousand urban. (Refer to Figures 3 and 4).



MERAMEC RIVER BASIN STUDY
POPULATION PROJECTION COMPARISONS
DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VI
KANSAS CITY, MO.
A — U.S. PROJECTION, SENATE SELECT COMMITTEE PRINT No. 5, MEDIAN MIGRATION ASSUMPTION No. 2
B — STATE OF MISSOURI, " " " " " " " " " " "
C — ST. LOUIS SMSA, " " " " " " " " " " "
D — TOTAL MERAMEC RIVER BASIN, U.S.P.H.S. PROJECTION
E — ST. LOUIS AND JEFFERSON COUNTIES IN BASIN, U.S.P.H.S. PROJECTION
F — TOTAL MERAMEC RIVER BASIN, MERAMEC BASIN CORP., HIGH
G — " " " " " " ", MEDIUM
POPULATION IN 1000'S
100,000
10,000
1,000
100
5
YEAR
1960
1980
2000
2020
2040
2060

FIGURE 3



MERAMEC RIVER BASIN STUDY

POPULATION PROJECTIONS
STUDY AREA

DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VI KANSAS CITY, MO.

FIGURE 4

VI. HYDROLOGY

Surface Water

The streamflows in the Meramec Basin are a result of rainfall, perennial springs, mine water and ground water discharges. There are twenty major springs in the Upper Basin which discharge a total average flow of 66 million gallons per day (mgd). (Refer to Exhibit No. 2). The largest spring, located on the Upper Meramec River, is the Meramec Spring, which discharges an average flow of 36 mgd; other spring flows range from 0.26 mgd to 4.6 mgd.

In the southeastern part of the basin, lead mining operations have increased the low flows in the Big and Meramec Rivers. Under present conditions, an average of 40 mgd is being pumped from the mines.

Streamflow data are available for ten U.S. Geological Survey stations which are located on the major streams. Limited streamflow data are available on the tributaries to the Meramec, Bourbeuse and Big Rivers. Therefore, to obtain minimum flow and frequency data for the tributaries, a method relating drainage area and streamflow was developed. This information was prepared and furnished by the U.S. Army Corps of Engineers.

After conventional treatment, the chemical quality of the surface water in the basin is satisfactory for most municipal and industrial purposes. A partial chemical analysis of the untreated Meramec River water at Kirkwood, Missouri, is presented in Exhibit No. 3. Sufficient chemical data are not available to make a detailed analysis of the chemical quality of the streams.

Currently, the Missouri Water Pollution Board is conducting an industrial and stream survey of the Meramec River Basin. Samples for chemical, physical, bacteriological, and biological analysis are being collected. This study will be completed in the summer of 1963 and a report entitled, "A Water Resource Inventory, Meramec Basin" will then be published.

Ground Water

The basin has extensive ground water resources except in the extreme northeastern corner of the area where the yield of ground water from the deep formations is limited. The major aquifers in the basin are the Roubidoux, Gasconade, Potosi formations and the Gunder member of the Gasconade formation. Well production and depths, with reference to the water bearing formations, are presented in Exhibit No. 4.

The permissible increase of ground water usage for the Meramec Basin was determined by the State of Missouri, Division of Geological Survey and Water Resources. The results were presented in the report "Ground Water Use and Production Capabilities, Meramec River Basin, Missouri" by Dale L. Fuller, Senior Geologist. This report presented the permissible increase of ground water as a multiple of present usage based on area and on both area and populalation density. The range of permissible increase varies from 6 to 59 times present usage.

The major source of ground water in the lower reach of the Meramec River is the alluvial deposits known as the Meramec River bottoms. Information indicating the potential yield of the alluvial aquifer is not available.

The chemical quality of ground water is satisfactory with low concentrations of chlorides, sulfates, and iron. The ranges are 3.2 to 62 parts per million (ppm) for chlorides, 0.01 to 0.3 ppm for iron, and 0.8 to 205 ppm for sulfates. The ground water is hard (range from 73 to 446 ppm as $CaCO_3$) and in the southeastern part of the basin some of the mine water exceeds 500 ppm total dissolved solids. The municipalities in the southern area now using mine water could obtain a fair

quality ground water from the Lamotte formation. The chemcial analyses of the public water supplies are presented in Exhibits Nos. 5 and 6. In general, these public water supplies meet the Public Health Service Drinking Water Standards. Chemical analysis of the mine water and perennial springs are presented in Exhibits Nos. 7 and 8, respectively. The quality of water from the Bonne Terre mine is poor and is not currently being used for municipal or industrial purposes. Spring water is high in iron with a range of 0.23 to 0.87 ppm.

VII. PRESENT WATER USE

The water resources of the Meramec River Basin are primarily used for municipal, industrial, and mining purposes. The total present municipal and industrial demands are approximately 30.5 million gallons per day (mgd). The largest demand is in the Lower Basin and amounts to about 25 mgd; however, the demand in the Lower Meramec Water Service Area is about ten mgd. The Lower Meramec Water Service Area is defined as that part of the basin which does not receive water from the Missouri River. (Refer to Figure No. 5). The present per capita use varies from 52 to 139 gallons per day and averages 70 gallons per capita per day (gpcd) in the Upper Basin and 110 gpcd in the Lower Basin.

The municipalities in the Bourbeuse River Basin use ground water as a source of supply. The municipality of Union had a combined ground and river water system; however, a new well capable of 600 gallons per minute was developed, eliminating the need for river intake.

In the Big River Basin, the municipal supplies are ground water from wells and mines. The Leadwood-Rivermines area primarily uses mine drainage water and the present consumption is approximately 1.5 mgd. Bonne Terre has abandoned the mine water supply because of poor chemical quality (total dissolved solids 922 ppm, sulfates 312 ppm) and is using well supplies.

The municipalities in the Lower Basin obtain water from the alluvial deposits and the Missouri and Meramec Rivers. A water treatment plant on the Missouri River supplies about 25 mgd to portions of the Lower Basin, and a St. Louis County plant on the Meramec River is used as a supplementary supply.

Additional information related to public water supplies in the Meramec

Basin is presented in Exhibit 9. This table summarizes the water supply source, treatment provided, population served, and consumption.

The lead mining operations in the southeastern part of the basin use six mgd for mining, milling and smelting operations. The demand is met by using the excess mine drainage water. The total excess drainage water which is pumped from the mines amounts to about 40 mgd.

Barite mining in the southeastern part of the basin uses approximately four mgd in the mill washing operations. The demand is met from various sources including small impoundments on minor tributaries.

The iron mining operations in the central part of the basin use from 0.2 to 1.8 mgd. There is not sufficient ground water to meet the demand. A pumping station on the Meramec River is being constructed approximately at river mile 110 to deliver 1.8 mgd to the Pea Ridge Mining area.

VIII. FUTURE WATER REQUIREMENTS

Water Supply

The future water supply requirements for the Meramec River Basin will be for municipal and industrial water supplies, for mining, for pulp mill operations and for recreation. The water needs are indicated for the base period of 1970 and future periods of 2020 and 2070. Storage requirements to meet projected needs should be based on the assumption that the needs will be met at a 98 percent probability level.

The increase in municipal and industrial water requirements during the study period is related to the population growth, industrialization, commercialization, and new developments of water using devices for the home. The Lower Basin is expected to have greater commercial and industrial development because of location with reference to the St. Louis SMSA. As a result, the amount of water used per capita will be greater in the lower area. However, the Upper Basin is expected to have a steady industrial and commercial growth. The following table indicated the expected water use, expressed in gallons per capita per day for the Upper and Lower Basins. The figures shown include light water using industries and commercial establishments.

Table No. 9

Water Demand
(gpcd)
Meramec River Basin

	1970	2020	2070
Lower Basin	120	150	200
Upper Basin	100	130	160

These figures are comparable to water use projections made in other studies of the area by private organizations and by other Federal and State agencies.

The municipal and industrial water demands for the Upper Basin are expected to reach eight million gallons per day (mgd) by 1970, 38 mgd by 2020 and 117 mgd by 2070. The present usage of ground water is approximately 16.5 mgd and according to a report prepared by the Missouri Geological Survey and Water Resources Division, the withdrawal of ground water may be increased to 280 mgd without depletion of the aquifers. Therefore, the future demands can be met without requiring storage in the proposed reservoir system. An analysis comparing the annual cost of using ground water and surface water was made and the results indicated that ground water was more economical.

The municipal and industrial demands of the Lower Meramec Water Service Area are expected to reach 16 mgd by 1970, 93 mgd by 2020, and 400 mgd by 2070. The portions of the basin and St. Louis SMSA now served from the Missouri and Mississippi Rivers are expected to continue to be served from those sources and the quantity of water is expected to be sufficient to meet future needs of these areas. (Refer to Figure No. 5). The remaining part of the Lower Basin could obtain water from the alluvial deposits, the Meramec River, or the Missouri River.

With the expansion of the present facilities in the Lower Basin, a demand of 50 mgd could be met without supplementary water from the Missouri River or from the proposed reservoir system. By the year 1995, additional water will be needed and by 2070, a demand of 350 mgd will have to be supplied from sources outside the Lower Basin. The requirements could be met by pumping water from the Missouri River or by constructing reservoirs on the Big, Meramec, or Bourbeuse River.

The water demands indicated for mining are average figures and large deviations can be expected because of the many factors which affect production. The total average demand for mining operations in the basin is expected to reach 13 mgd by 1970 and reach a maximum of 20 mgd by 2000. After 2000, many of the mining operations are expected to phase out.

The water requirements for a barite mining operation, which produced about 100 tons of barite concentrates per 24 hour day, are about 1,000 to 1,200 gallons per minute (gpm); however, the majority of the water is recirculated and the net water demand is approximately 400 gpm. The water needs are expected to reach 5 mgd by 1970 and 6 to 7 mgd by 2000. After 2000, the barite operation will be phasing out, with little or no water demand by 2020. The demands can be met from ground water sources or from small private surface water impoundments.

Water requirements for the lead mining operations are expected to reach 7 mgd by 1970 and 10 mgd by 2000. The indicated water requirements are the net water demands which amout to about 15 percent of the total water requirements. After 2000, the lead mining will be phased out. The water demand can be met by utilization of excess mine drainage water.

The iron mining operations in the basin will increase throughout the study period. The water requirements are expected to reach 1 mgd by 1970, 4 mgd by 2020 and 8 mgd by 2070, assuming no recirculation. If the water is recirculated, the net new water needs would be from 10 to 30 percent of the amounts shown. The demand could be met from ground water sources with the exception of the Pea Ridge Area, which requires a supplemental water source. Pumping facilities are being installed to supply this area with water from the Meramec River. The present flow in the Meramec River is adequate without reservoirs to meet present and

future water requirements.

A 300 ton per day pulp mill is expected to be established in the southeastern part of the basin by 1970.[49] The mill will require approximately 9 mgd which will remain constant for the study period. The demand can be met by using mine drainage water.

The impact of recreation in the basin is not expected to create any water supply problems. The most significant area will be at the Virginia Mines and Meramec Park Reservoirs. According to information provided by the Bureau of Outdoor Recreation and the U.S. Army Corps of Engineers, the number of visitors on the peak day is expected to reach 182,000 by 1970, 260,000 by 2020, and 410,000 by 2070. Assuming ten gallons per visitor per day[48], the demand will be about two mgd by 1970, three mgd by 2020, and four mgd by 2070. Wells located at the recreational sites could supply sufficient water to meet these needs.

Quality Control Water

The need for quality control water in the Meramec Basin was determined by considering the effects of domestic, industrial, and natural pollution on the receiving streams. To provide desirable stream condition in the Meramec Basin, a satisfactory oxygen content should be maintained, desirable chemical concentrations should not be exceeded, and bacteriological requirements should be met. Storage to meet quality control requirements should be based on the assumption that the needs would be met at a 95 percent probability level.

Basic data indicating the present sources of domestic and industrial pollution has been released and appears in the Appendix as Exhibit No. 11.

An evaluation of projected data relative to wastes indicated that the major contributors are expected to be the pulp mill and municipalities. The largest waste loads discharged to the streams would be in the Lower Basin. Few waste problems are expected from recreation and mining operations. It was assumed that all municipalities would have a minimum of secondary treatment and chlorination. Under this assumption bacteriological considerations were assumed to have been satisfied without quality control water. With respect to Alkyl Benzene Sulfonate (ABS), it was assumed that future waste treatment would be able to produce an effluent not exceeding 0.5 ppm of ABS(Public Health Service Drinking Water Standards, 1962) through the use of advanced waste treatment methods or through regulatory measures which would prohibit the manufacturing of the non-degradable surfactants for detergents.

The chemical quality of the streams meets most requirements; however, sufficient data are not available to make a detailed anlaysis. Present and projected data relative to chemical quality indicated that quality control water would not be needed in the foreseeable future. No problems are expected from irrigation return flows because of the limited amounts of irrigable land in the basin.

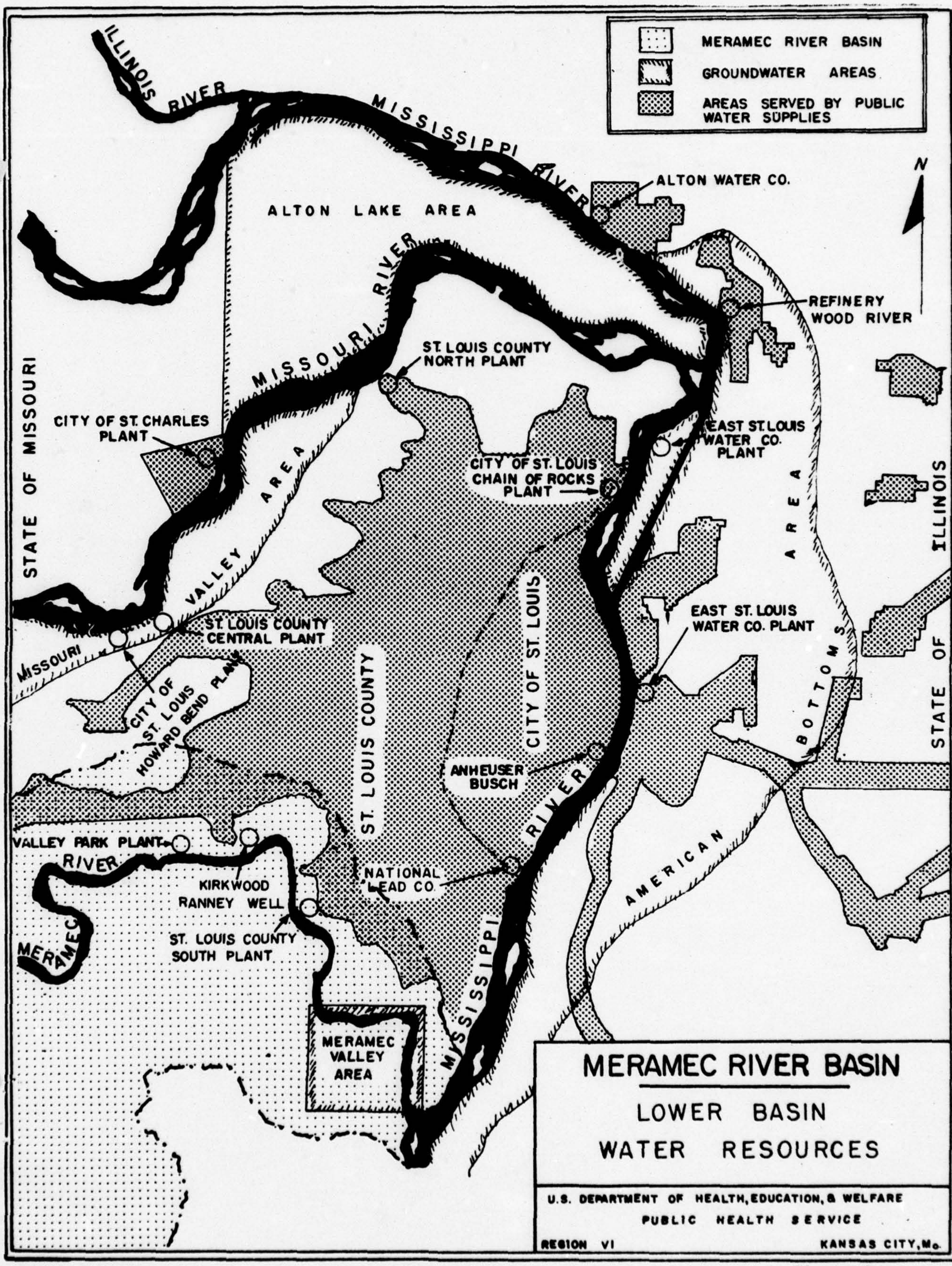

MERAMEC RIVER BASIN
GROUNDWATER AREAS
AREAS SERVED BY PUBLIC WATER SUPPLIES
ILLINOIS RIVER
MISSISSIPPI RIVER
ALTON WATER CO.
N
ALTON LAKE AREA
MISSOURI RIVER
REFINERY WOOD RIVER
ST. LOUIS COUNTY NORTH PLANT
STATE OF MISSOURI
CITY OF ST. CHARLES PLANT
EAST ST. LOUIS WATER CO. PLANT
CITY OF ST. LOUIS CHAIN OF ROCKS PLANT
STATE OF ILLINOIS
VALLEY AREA
ST. LOUIS COUNTY CENTRAL PLANT
EAST ST. LOUIS WATER CO. PLANT
MISSOURI
CITY OF ST. LOUIS HOWARD BEND PLANT
ST. LOUIS COUNTY
CITY OF ST. LOUIS
AMERICAN BOTTOMS AREA
ANHEUSER BUSCH
VALLEY PARK PLANT
RIVER
KIRKWOOD RANNEY WELL
NATIONAL LEAD CO.
ST. LOUIS COUNTY SOUTH PLANT
MERAMEC
MISSISSIPPI RIVER
MERAMEC VALLEY AREA
MERAMEC RIVER BASIN
LOWER BASIN
WATER RESOURCES
U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VI
KANSAS CITY, Mo.

Figure 5

In the mining industry, the wastes are primarily from wash waters and consist of colloidal silts and clay. Large sedimentation ponds remove most of the sediment before the waste water is discharged to the streams. Organic chemicals are used for the flotation process in the lead mining operations; however, the liquid is recirculated and the chemicals are not discharged to the streams.

The wastes from the proposed pulp mill will be primarily organic and are expressed in terms of Biological Oxygen Demand (BOD). The mill is expected to discharge 25,000 pounds of BOD (5 days at 20° C.) per day and after treatment, release approximately 1,250 pounds of BOD (5 days at 20° C.) per day to the receiving stream. The treatment would consist of lagooning the wastes in an existing 530 acre sedimentation pond.

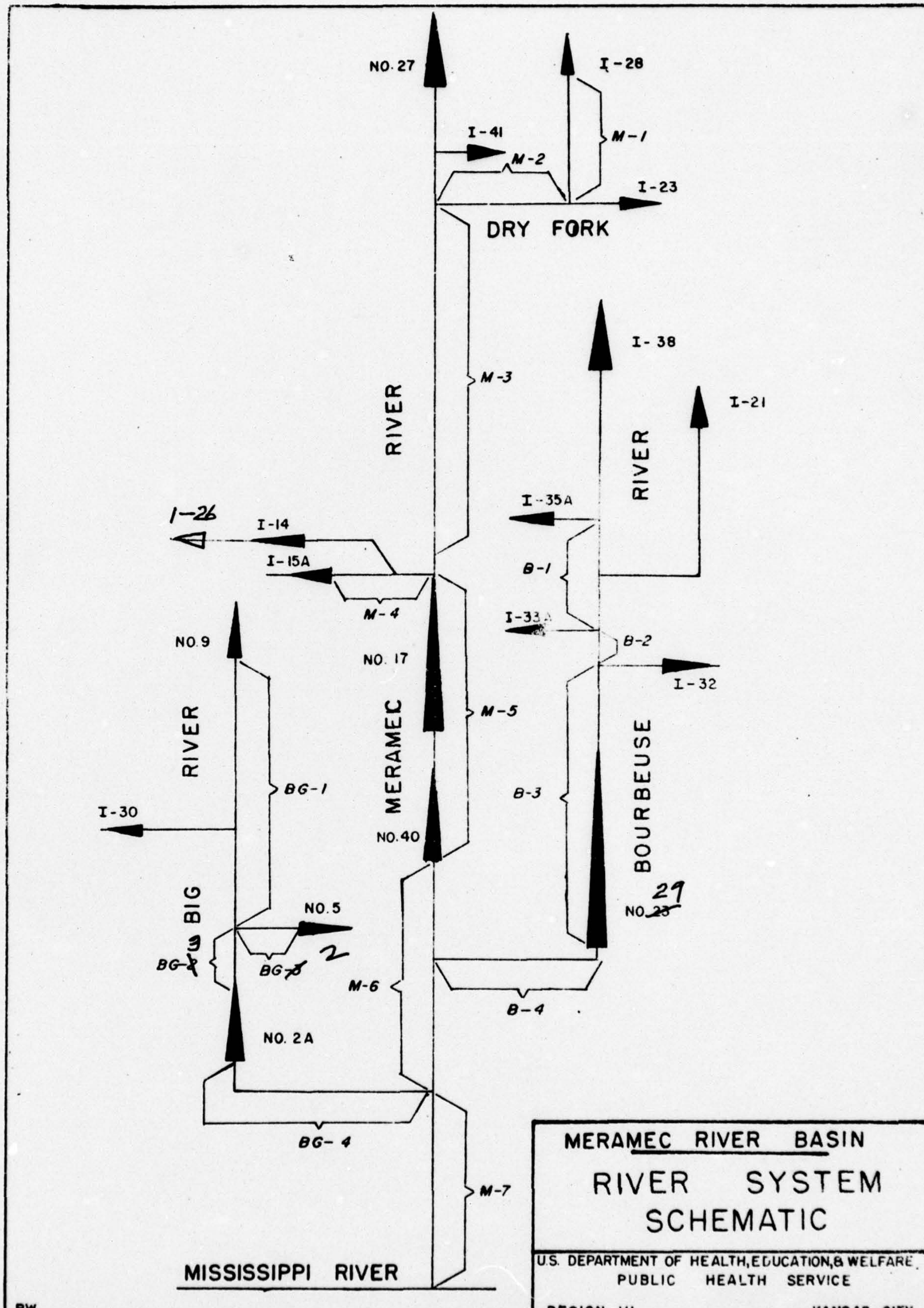
Quality control needs were based on dissolved oxygen considerations and were determined for specific reaches of the major streams for the spring, summer, fall and winter seasons. It was assumed that all reservoirs would be constructed and quality control water would be available from the major and intermediate reservoirs. No storage was considered available from the headwater reservoirs because of their limited storage capacities.

A summary of the quality control needs is given in Table No. 10 and a schematic of the basin indicating the reaches in which flows are needed is shown in Figure 6. The flows shown on Table 10 are based on no natural flow in the streams. This is not a realistic situation, but the assumption of zero flows was necessary because of the delay in getting the required information on natural low flows. When the required information becomes available, it will be necessary to subtract the natural low flows from the

figures in Table 10 for each reach to arrive at the flows which must be provided from storage.

The figures in Table 10 for reaches B-1 through B-3 and M-2 through M-3 are total needs and represent water and wastes from the reach above. The quality control demands for reach B-4 and M-7 do not include quality control flows from upstream reaches as it was assumed the upstream flows would be intercepted by major reservoirs above the reaches in question.

Some problems may arise from pollution loads entering the reservoirs and special studies or investigation may need to be initiated to find a feasible solution. Currently sufficient technical data are not available to make generalizations for the Meramec Raver Basin as to the most feasible and economical solution to this potential problem.



MERAMEC RIVER BASIN

RIVER SYSTEM SCHEMATIC

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE

REGION VI KANSAS CITY

FIGURE No. 6

Table No. 10

Summary of Water Quality Needs

Meramec River Basin

Reach	1970			2020			2070		
	Spring & Fall	Winter	Summer	Spring & Fall	Winter	Summer	Spring & Fall	Winter	Summer
B-1	1	1	2	2	1	6	3	1	21
B-2	3	2	5	9	4	18	23	6	55
B-3	4	3	6	10	5	19	24	7	56
B-4	3	1	8	7	1	26	9	1	53
BG-1	10	4	30	20	2	57	28	6	80
BG-2	-	-	-	-	-	-	-	-	-
BG-3	-	-	-	-	-	-	-	-	-
BG-4	-	-	-	-	-	-	-	-	-
M-1	-	-	-	-	-	-	-	-	-
M-2	2	1	5	2	1	10	1	2	15
M-3	11	5	23	21	7	52	38	4	106
M-4	-	-	-	-	-	-	-	-	-
M-5	-	-	-	-	-	-	-	-	-
M-6	Flows required for Reach M-7 satisfy M-6 needs								
M-7	60	24	130	230	80	510	380	20	1,100

IX. VALUE OF STORAGE

To determine the value of future water supply and quality control needs, tangible and intangible benefits need to be analyzed. Because of the difficulty in measuring the value of the intangibles an alternate cost method was used to provide an approximate value for future water needs.

In the Upper Basin, water supply needs could be met from well systems or from reservoirs. A cost analysis was made for treated ground water and treated surface water assuming the surface water cost $0.0 at the plant intake. The results indicated that ground water would be more economical; therefore, no value should be allotted to storage in Federal reservoirs for water supply in the Upper Basin.

In the Lower Basin, the water supply needs could be met by obtaining water from the Missouri River or from the Meramec River. An economic evaluation was made of the cost of pumping water from the Missouri River, but because of the lack of hydrologic data, it was impossible to evaluate the cost of providing storage in a single purpose reservoir in the Upper Basin, but available data from the Corps of Engineers indicates that the average annual cost of a single purpose reservoir to supply municipal water would be far in excess of the cost of pumping water from the Missouri River. Exhibit No. 11 gives pertinent cost data figures which are available at the present time.

Because of the lack of hydrologic information and reservoir cost data, it has been impossible to determine the value of demands for quality control water. It has been determined that the only reasonable alternative to the

multipurpose system is construction of single purpose reservoirs in the Meramec River Basin.

The Bureau of Outdoor Recreation expects about 11,660,000 annual visitor-days in the Meramec River Basin by 1970. Improvements of instream uses will be realized by providing quality control water and these will be widespread in nature.

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XI. APPENDIX

Exhibit No. 1

RESERVOIR DATA

MERAMEC RIVER BASIN

RESERVOIR	FLOOD CONTROL POOL STORAGE (Acre-Feet)	MIN. CONSERVATION POOL (100-YEAR SEDIMENT CAP) STORAGE (Acre-Feet)	NET STORAGE JOINT-USE POOL (Acre-Feet)	TOTAL STORAGE (Acre-Feet)
I-14	27,535	3,942	3,923	35,400
I-15A	29,590	4,755	3,655	38,000
I-21	6,470	1,637	513	8,620
I-23	9,520	2,144	1,026	12,690
I-26	7,305	1,786	16,909	26,000
I-28	11,760	2,467	11,773	26,000
I-30	5,480	1,472	148	7,100
I-32	15,785	3,013	7,202	26,000
I-33A	13,845	2,733	9,422	26,000
I-35A	18,040	3,298	4,662	26,000
I-38	29,585	4,715	4,700	39,000
I-41	7,745	1,868	712	10,325
H-3	2,700	899	--	3,600
H-4	2,500	868	--	3,300
H-5	1,000	306	--	1,300
H-6	2,900	976	24	3,900
H-8	5,000	1,390	310	6,700
H-9	2,300	823	--	3,100
H-10	1,300	568	--	1,800
H-11	3,600	1,095	105	4,800
H-13	5,000	1,405	295	6,700
H-25	3,900	1,165	135	5,200
H-31	1,700	673	--	2,300
H-40	--	511	389	900

Exhibit No. 2

Spring Flows from Large Privately Owned Springs*

Meramec River Basin

Spring Number	Spring	River Miles** Above Mouth	Flow Million Gallons/Day
54	Kratz	64-40-15	4.39
107	McDade	64-110-30	0.52
78	Roaring	95	0.65
15	Blue	118	3.17
65	Onondage	130	0.77
50	James	132-6	1.43
92	Westover	132-5-3	4.07
96	Woodlock	132-25	1.30
36	Evans	140-4	0.26
30	Collins	140-8	1.03
59	McIntosh	152	0.61
77	Roaring	158	2.65
76	Richart	160	0.81
21	Brook	165	0.40
60	Meramec	165	36.2
109	Mint	200	0.39
48	Howes Mill	200-25	4.59
100	Cold	37-62-25	0.45
73	Racing	37-62-30	1.51
47	Hopewell	37-70-10	1.31

*From Missouri Water Resources Map
**River mile prefix of 37 indicates The Big River and 64 indicates the Bourbeuse River

Exhibit No. 3

Chemical and Physical Characteristics

of Untreated Meramec River Water at Kirkwood, Missouri**

Meramec River Basin

Year	Temperature (°F)	Turbidity (ppm)*	pH	Alkalinity as $CaCO_3$ (ppm)*	Hardness as $CaCO_3$ (ppm)*
1940	60	66	8.0	159	184
1941	63	73	8.0	142	174
1942	61	137	8.0	140	178
1943	62	87	8.1	156	196
1944	61	83	-	162	188
1945	58	112	7.9	147	179
1946	62	89	7.9	148	194
Average	61	92	8.0	150	185

*Parts Per Million
**From Geological Survey Circular 216, 1952

Exhibit No. 4

Well Data

Meramec River Basin

Formation and Well	County	Total Depth Feet	Production (Gallons per Minute)
GUNTER MEMBER OF GASCONADE FORMATION			
1. Boys Town of Mo. St. James	Phelps Co.	300	42
2. Oak Meadow (Country Club)	Phelps Co.	550	100
POTOSI FORMATION			
1. Bourbon (No. 2)	Crawford Co.	501	73
2. Cuba (No. 2)	Crawford Co.	1005	233
3. Salvation Army (Blue Spring)	Crawford Co.	530	?
4. Pres. Ch.	Crawford Co.	500	56
5. Steelville (No. 2)	Crawford Co.	535	?
6. Steelville (2A)	Crawford Co.	660	287
7. U.S.C.C.C.F. 13 (#1)	Washington Co.	501	35
8. St. James (2A)	Phelps Co.	1100	360
9. Rolla (No. 1)	Phelps Co.	930	200
10. Rolla (No. 6)	Phelps Co.	1150	580
11. Rolla (No. 8)	Phelps Co.	1125	550
12. Rolla (No. 4)	Phelps Co.	1175	300
13. Rolla (No. 7)	Phelps Co.	1215	585
14. Rolla (No. 5)	Phelps Co.	1078	540
15. Rolla (Mo.School of Mines)(2B)	Phelps Co.	1151	328
16. Owensville (No. 1)	Gasconade Co.	900	200
17. Owensville (No. 2)	Gasconade Co.	962	79
18. Owensville (No. 3)	Gasconade Co.	1000	?
19. Salem (No. 1)	Dent Co.	710	93?
20. Indian Trail St. Park (No. 2)	Dent Co.	455	25
21. Union	Franklin Co.	1000	349
22. St. Clair (No. 4)	Franklin Co.	838	36
23. St. Clair (No. 3A)	Franklin Co.	800	80
24. Meramec St. Park (No. 1)	Franklin Co.	605	25
25. Hillsboro (No. 2)	Jefferson Co.	1310	100
ROUBIDOUX FORMATION			
1. Gray Summit (School)	Franklin Co.	590	25
2. U. S. Government (Nike Base)	Franklin Co.	680	52

Exhibit No. 4

Well Data, cont'd

Meramec River Basin

Formation and Well	County	Total Depth Feet	Production (Gallons per Minute)
GASCONADE FORMATION			
1. Rosebud (No. 1)	Gasconade Co.	508	35
2. Eureka	St. Louis Co.	800	135
3. Pacific (2)	Franklin Co.	765	241
4. Pacific (No. 1)	Franklin Co.	650	150
5. Cedar Hill (No. 1)	Jefferson Co.	650	30
EMINENCE FORMATION			
1. Cuba (No. 1)	Crawford Co.	602	125
2. Bible Pres. Ch. (boy & girls Camp)	Crawford Co.	375	12
3. St. James (No. 1)	Phelps Co.	700	75
4. Vichy Airport (No. 1)	Maries Co.	850	103
5. Vichy Airport (No. 2)	Maries Co.	950	225
6. Rosebud (No. 2)	Gasconade Co.	700	96 1/2
7. Cedar Hill (No. 2)	Jefferson Co.	902	50
8. Hillsboro (No. 1)	Jefferson Co.	931	65
BONNE TERRE FORMATION			
1. Ironton (No. 6)	Iron Co.	300	36
2. Ironton (No. 4)	Iron Co.	424	46
3. Ironton (No. 1)	Iron Co.	293	70
4. Ironton (No. 2)	Iron Co.	467	18

Exhibit No. 5

Chemical Analysis of Public Water Supplies
Meramec River Basin
(Results in Parts Per Million)

City	Treated or Raw	Total Dissolved Solids	Chlorides (Cl^-)	Sulfates ($SO_4^{=}$)	Hardness ($CaCO_3$)	Iron (Fe)	Source
Franklin County							
Pacific	treated	382	6.4	12.8	312	0.3	Wells
Union	treated	221	7.3	41.2	140	0.02	Bourbeuse R. Aux. - Well
St. Clair	raw	222	5.0	10.9	180	0.06	Wells
Sullivan	raw	192	4.1	7.6	162	0.01	Wells
Gerald	raw	380	4.5	10.9	316	0.14	Wells
Gasconade County							
Owensville	treated	305	5.5	18.3	256	0.14	Wells
Maries County							
Belle	raw	287	3.2	32.5	188	0.2	Wells
Phelps County							
St. James	raw	549	7.7	141.2	410	0.03	Wells
Rolla	raw	356	5.9	32.9	282	0.1	Wells
Dent County							
Salem	raw	263	5.9	[illegible].8	212	0.4	Wells

Exhibit No. 5
(Page 2)

Chemical Analysis of Public Water Supplies

Meramec River Basin
(Results in Parts Per Million)

City	Treated or Raw	Total Dissolved Solids	Chlorides (Cl^-)	Sulfates ($SO_4^=$)	Hardness ($CaCO_3$)	Iron (Fe)	Source
Crawford County							
Steelville	raw	243	5.5	2.3	202	0.02	Wells
Cuba	raw	272	3.6	8.0	226	0.03	Wells
Bourbon	raw	204	5.0	2.1	172	0.02	Wells
Washington County							
Potosi	raw	320	6.4	22.0	238	0.14	Wells
Iron County							
Viburnum	treated	245	7.3	19.1	180	0.09	Well
St. Francois County							
Bismarck	raw	481	13.2	95.3	358	0.1	Wells
Leadwood	treated	427	11.4	63.0	296	0.01	Mine water
Elvins	treated	635	20.9	205.1	446	0.2	Mine water
Esther	treated	635	20.9	205.1	446	0.2	Mine water
Rivermines	treated	635	20.9	205.1	446	0.2	Mine water
Deslodge	treated	635	20.9	205.1	446	0.2	Mine water
Flat River	treated	635	20.9	205.1	446	0.2	Mine water
Bonne Terre	treated	-	-	-	-	-	Well

Exhibit No. 5
(Page 3)

Chemical Analysis of Public Water Supplies

Meramec River-Basin
(Results in Parts Per Million)

City	Treated or Raw	Total Dissolved Solids	Chlorides (Cl^-)	Sulfates ($SO_4^=$)	Hardness ($CaCO_3$)	Iron (Fe)	Source
Jefferson County and St. Louis County							
Hillsboro	raw	357	3.6	25.3	294	0.03	Wells
Valley Park	treated	315	29.1	65.2	198	0.04	Wells
Manchester		---	12.0	21.0	73	0.00	St. Louis County Water Company
Des Peres		---	12.0	21.0	73	0.00	St. Louis County Water Company
Kirkwood	treated	329	62.2	65.4	126	0.01	Rainey Well-Aux. Meramec River, St. Louis County Water Company
Fenton	treated	---	12.0	21.0	73	0.00	St. Louis County Water Company
Balwin	treated	---	12.0	21.0	73	0.00	St. Louis County Water Company
Eureka	raw	409	24.1	24.7	326	0.03	Well

Exhibit No. 6

Chemical Quality of Treated and Untreated Water*
(Parts Per Million except Color, pH, and Conductance)

Meramec River Bottoms

	Untreated	Treated
Silica (SiO_2)	11	9.2
Iron (Fe)	.03	.02
Manganese (Mn)	.00	.00
Calcium (Ca)	65	21
Magnesium (Mg)	26	18
Sodium (Na)	21	20
Potassium (K)	1.8	1.0
Carbonate (CO_3)	0	18
Bicarbonate (BCO_3)	239	36
Sulfate (SO_4)	61	65
Chloride (Cl^-)	41	31
Fluoride (F)	.0	.1
Nitrate (NO_3)	1.3	1.0
Dissolved Solids	420	244
Hardness as $CaCO_3$		
Total	267	128
Noncarbonate	71	68
Color	2	2
pH	7.2	9.5
Specific Conductance	585	373
Turbidity	3	.2
Date of Collection	4-14-51	4-14-51

Treatment - Aeration, softening with quicklime, prechlorination, mechanical flocculation, sludge removal, settling, filtration, and postchlorination.

*Radial - Screened well, Kirkwood, Mo. from Geological Survey 216

Exhibit No. 7

Chemical Analysis of Mine Water*
(Results in ppm except for ph)

Meramec River Basin

	Mine	
	Leadwood	Bonne Terre
CaO	98	120
MgO	52	107
Fe	Trace	0.5
Al_2O_3	Nil	Trace
Cl	23	19
SO_4	69	312
Total dissolved solids	486	922
Total alkalinity	236	290
pH	7.7	8.0

*Missouri Wood Study, EBASCO, 1962

Exhibit No. 8

Analysis of Spring Water
(Results in Parts Per Million)

Meramec River Basin

Spring	River Mile*	Suspended Solids	Total Hardness As ($CaCO_3$)	Alkalinity As ($CaCO_3$)	Iron (Fe)	Calcium (Ca)	Sodium & Potassium (Na)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)
Krate	64-40-15	19	124	118	0.23	25.5	1.4	8.0	2.7	0.98
Meramec	165	1.4	149	148	0.87	30.2	3.3	2.7	2.4	1.73
Onandaga	130	Trace	221	216	0.44	47.6	2.2	4.3	2.7	1.39
Roaring	95	1.3	180	165	0.58	36.5	1.9	10.5	6.6	1.06

*Estimated

Exhibit No. 9

Public Water Supplies

Meramec River Basin

County Municipality	Pop. 1960	Pop. Served	Water Supply Source	Ownership	Treatment	Millions Gallons per Day (mgd) Capacity	Millions Gallons per Day (mgd) Consumption	Gallons per Capita per Day (gpcd)
Franklin								
Pacific	2,795	2,650	Ground	Municipal	F	0.576	0.170	64
Union	3,937	4,100	Ground & River	Municipal	C-F-D	1.32	0.55	134
St. Clair	2,711	2,690	Ground	Municipal	None	0.360	0.20	74
Sullivan	4,098	4,050	Ground	Municipal	None	1.73	0.375	93
Gerald	474	459	Ground	Municipal	None	0.21	0.035	77
Gasconade								
Owensville	2,379	2,550	Ground	Municipal	F	0.72	0.225	88
Maries								
Belle	1,016	1,000	Ground	Municipal	None	0.30	0.07	70
Phelps								
St. James	2,384	2,350	Ground	Municipal	None	1.44	0.15	64
Rolla	11,132	11,049	Ground	Municipal	D	2.88	0.8	72
Dent								
Salem	3,870	4,750	Ground	Municipal	D	0.27	0.54	114
Crawford								
Steelville	1,127	1,150	Ground	Municipal	None	0.43	0.06	52
Cuba	1,672	1,640	Ground	Municipal	None	0.50	0.175	107
Bourbon	779	750	Ground	Municipal	None	0.12	0.055	74
Washington								
Potosi	2,805	2,850	Ground	Municipal	D	0.72	0.18	63
Iron								
Viburnum	590	250	Ground	Private	H-F	0.648	0.180	-

Exhibit No. 9

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MERAMEC RIVER, MISSOURI COMPREHENSIVE BASIN STUDY. VOLUME VI. A--ETC(U)
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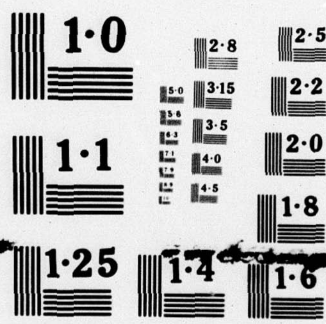
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Exhibit No. 9 (cont'd)

Public Water Supplies

Meramec River Basin

County Municipality	Pop. 1960	Pop. Served	Water Supply Source	Ownership	Treatment	Millions Gallons per Day (mgd) Capacity	Millions Gallons per Day (mgd) Consumption	Gallons per Capita per Day (gpcd)
St. Francois								
Bismark	1,237	1,400	Ground	Municipal	None	0.35	0.15	107
Bonne Terre	3,219	4,025	Mine Water	Private	F-D	0.87	0.30	75
Leadwood)			Mine Water	Private	F-D	0.45		
Elvins)	Total Population		Mine Water	Private	F-D	Total	Total	
Esther)	of these six		Mine Water	Private	F-D	Capacity	Consumption	
Rivermines)	municipalities		Mine Water	Private	F-D	2.02	1.03	72
DesLodge)	14,307		Mine Water	Private	F-D			
Flat River)			Mine Water	Private	F-D			
Jefferson & St. Louis								
Hillsboro	457	392	Ground	Municipal	None	0.210	0.035	90
Valley Park	3,452	3,363	Ground	Municipal	H-F-D	1.162		134
Fenton	1,046	1,046	Surface	Private	F-D	-	-	-
Eureka	1,134	1,050	Ground	Municipal	None	0.08	0.66	-
Kirkwood	29,421	29,500	Ground & River	Municipal	H-F-I-D	3.61	2.25	76

F - Filtration
C - Coagulation
D - Disinfection
H - Softening
I - Iron Removal

Exhibit No. 10

Summary of Alternative Cost Computations

Meramec River Basin

Alternative	Construction Cost ($1,000)	Annual Cost Amortized 50 Yrs. @ 4% ($1,000)	Operation & Maintenance Cost ($1,000)	Total Annual Cost ($1,000)	Year of First Need	1970 Worth of Annual Cost ($1,000)
Municipal and Industrial Water Supply - Upper Basin - 10 mgd Plant						
Well system with Zeolite Pressure Filters	1,460	9.3*	55	148	1970	148
Water Treatment Plant Surface Water	1,100	51	124	175	1970	175
Municipal and Industrial Water Supply - Lower Basin						
Missouri River Pumping System	3,250	151	440	591	1995	220
	5,200	242	1,320	1,560	2020	220
	10,400	485	3,100	3,830	2045	200
					Total	640
Meramec Basin Single Purpose Reservoir System	**	**	**	**	**	**
Quality Control Water Meramec River Basin						
Meramec Basin Single Purpose Reservoir System	**	**	**	**	**	**

*Amortized for 25 years @ 4%
**Data unavailable

Exhibit No. 11

Basic Data on Sources of Pollution*

Meramec River Basin

Location	River Miles Above Mouth	Population 1960	Population Sewered	P.E. (BOD) Design	P.E. (BOD) Raw	Nature of Wastes	Treatment Provided	Discharged P.E. (BOD)	Discharged Q
Meramec River	1,145								
Henke, Arnold, Ten Brook & Vic	2	Approx. 6000 Pop. in 12 sq. miles							
Ten Brook, Maxville & Vic	3.5					Domestic	Private System		
Mattesse Creek	4	Approx. 4500 Pop. in 12 Sq. Miles				Domestic	Private System		
Saline - Sugar Creek	10	Approx. 8000 Pop. in 17 Sq. Miles				Domestic	Private System		
Fenton	15	1,046	300		300	Domestic	Secondary	30	
Sunset Hills	15.5	3,525							
St. Louis Co. Water Co	16					Sludge	Holding Pond		
Kirkwood Water Plant	18					Sludge	None		
Chrysler Corp.	19.5					Ind. & Dom	Neutralization Lagoons		
Kirkwood #2 Plant	20-4-0.5	29,421	9,000	12,000	9000	Domestic	Secondary & Lagoon	900	
Manchester-Winchester	20-6	2,021		4,500		Domestic	Secondary		
Ramco Corp(Manchester)	20-65					Industrial	None		168,000 gpd
Valley Park	21	3,452	2,600	4,500	2600	Domestic	None	2,600	

Exhibit No. 11

Exhibit No. 11 (cont'd)

Basic Data on Sources of Pollution*

Meramec River Basin

Location	River Miles Above Mouth	Population 1960	Population Sewered	P. E. (BOD) Design	P. E. (BOD) Raw	Nature of Wastes	Treatment Provided	Discharged P.E. (BOD)	Discharged Q
Archer, D. Midland Co	21					Industrial	None till FY64		200 gpm
Absorbent Cotton Co	21					Industrial	None till FY64		8 dumps at 2,000 gal.
Meramec Hills Sub.			45		45	Domestic	Secondary	4.5	
Riverside Sub.			200		200	Domestic	Secondary	20	
Fawn Ridge Sub.			100		100	Domestic	Secondary	10	
Bellwin	22-2	5,710	2,655			Domestic	Secondary		
Eureka	32	1,134		970	970	Domestic	Secondary	120	
High Ridge Vic., Artie Creek	34	Approx. 2000 People in area				Domestic	Private System		
Big River	37-58-3								
Potosi	37-58-15.5-9	2,805	2,750	3,500	2750		Secondary & Lagoon	275	
Apex Mining Co.	37-68-8					Tiff, washing from Mill			1.3 mgd
Bonne Terre	37-79.5-2	2,900		3,800		Domestic		Under Construction	
Bonne Terre	37-85.5-1	320		400		Domestic		Under Construction	
Desloge	37-91	2,308				Domestic	Lagoon	Under Construction	

Exhibit No. 11 (cont'd)

Exhibit No. 11 (cont'd)

Basic Data on Sources of Pollution*

Meramec River Basin

Location	River Miles Above Mouth	Population 1960	Population Sewered	P.E. (BOD) Design	P.E. (BOD) Raw	Nature of Wastes	Treatment Provided	Discharged P.E. (BOD)	Discharged Q
Esther	37-91-1.5-1	1,033					Private System		
Flat River	37-91-3	4,515	3,720	6,000	3720	Domestic	Primary	3,720(Plant Bypassed)	
Federals (River Mines, Mill #17, Mine #11, & Rim Mines)	37-91-3.5					Industrial	None		16.9 mgd pumped at night only
River Mines	37-91						Private System		
Elvins	37-91	1,818					Private System		
Leadwood	37-100	1,343					Private System		
Leadwood Mine & Mill	37-100-1								16.9 mgd pumpe[illegible] at night only
Irondale	37-110-2	335				Industrial	Private System		
Bismarck	37-110-7	1,237	995	1,200	995	Domestic	Secondary	250	
Meramec River									
Pacific	49	2,795	2,400	3,600	2400	Domestic	Lagoon	240	
Bourbeuse River	64								
Union	64-16	3,937	3,800	7,400	4400	Ind. & Dom.	Lagoon	440	

Exhibit No. 11 (cont'd)

Exhibit No. 11 (cont'd)

Basic Data on Sources of Pollution*

Meramec River Basin

Location	River Miles Above Mouth	Population 1960	Population Sewered	P.E. (BOD) Design	P.E. (BOD) Raw	Nature of Wastes	Treatment Provided	Discharged P.E. (BOD)	Discharged Q
St. Clair	64-18-4	2,711	2,440	3,200	2440	Domestic	Secondary	244	
Sullivan #1	64-47-15-1	4,098	1,230	4,500	1230	Domestic	Lagoon	120	
Sullivan #2 & #3	64-47-17	4,098	2,450	4,500	2450	Domestic	Lagoon	245	
Ramco Corporation	64-47-19					Plating	None		0.16 mgd
Bourbon	64-79-13-1	779		636		Domestic	Lagoon	Under Construction	
Owensville	64-86-10-1	2,379	2,200	4,500	2200	Ind. & Dom.	Lagoon	220	
Bland	64-104-17-2	654	600	594	600	Domestic	Lagoon	60	
Belle	64-104-24-1.5	1,016	900	2,000	900	Domestic	Lagoon	90	
Cuba	64-109-14-6	1,672	1,000	1,440	1000	Ind & Dom	Lagoon	100	
Cuba	64-109-14-4-1	1,672	400		400	Domestic	Lagoon	50	
St. James	64-139-5	2,384	100	120	100	Domestic	Lagoon	10	
Meramec River									
Meramec Mining Co (Pea Ridge)	85-11-1-2			478	200	Iron Mine, Drainage, Domestic	Lagoon	20	
Indian Creek Shaft #25	85-13-7					Lead Mine Drainage			0.72 mgd Continuous
Viburnum Shaft #28 & Mill	131-1-27-3-2					Lead Mine Drainage			3.17 mgd Continuous

Exhibit No. 11 (cont'd)

Exhibit No. 11 (cont'd)

Basic Data on Sources of Pollution*

Meramec River Basin

Location	River Miles Above Mouth	Population 1960	Population Sewered	P.E. (BOD) Design	P.E. (BOD) Raw	Nature of Wastes	Treatment Provided	P.E. (BOD)	Q
Viburnum	131-1-27-3-2	590	600	650	600	Domestic	Lagoon	60	
Viburnum Shaft #27	131-27-2					Lead Mine Drainage			3.17 mgd
Steelville	146-2	1,127	1,000	2,000	1000	Domestic	Secondary	100	
St. James	167-3-2	2,384	1,200	3,450	1200	Domestic	Secondary &Lagoon	120	
Rolla (East)	167-18-5-1	11,132	4,100	5,000	4400	Domestic &Industrial	Secondary	450	
Rolla (South)	167-18-5-1	11,132	6,700	12,000	7500	Domestic & Industrial	Secondary	750	
Salem	167-51-8	3,870	3,290	3,800	3290	Domestic	Secondary	330	

*From Missouri Water Pollution Board, October 1962

Exhibit No. 12

AGENCIES WHICH HAVE CONTRIBUTED TO THE

MERAMEC RIVER BASIN STUDY

1. U. S. Army Engineer District, St. Louis, Corps of Engineers
2. U. S. Bureau of Mines, Region IV, Oklahoma
3. U.S. Forest Service, North Central Region, Wisconsin
4. Area Redevelopment Administration, Missouri
5. National Park Service, Region 2, Nebraska
6. Missouri Water Pollution Board, Missouri
7. Missouri Division of Health, Missouri
8. State of Missouri, Division of Geological Survey and Water Resources, Missouri
9. Missouri Conservation Commission, Missouri
10. Missouri Water Resources Board, Missouri
11. St. Louis County Health Department, Missouri
12. Jefferson County Health Department, Missouri
13. St. Louis County Planning Commission, Missouri
14. Metropolitan St. Louis Sewer District, Missouri
15. Community Development, University of Missouri Extension, Missouri
16. Meramec Basin Corporation, Missouri
17. St. Louis County Water Company, Missouri
18. Layne-Western, Missouri
19. E. B. A. S. Co. Consulting Firm
20. Representatives of the Municipalities in the Basin

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
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ST. LOUIS 2, MISSOURI